THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

VOLUME THE SEVENTEENTH.

1861.

PART THE FIRST.

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

LONDON:

LONGMAN, GREEN, LONGMANS, AND ROBERTS.

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SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

MDCCCLXI.

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Elected February 15th, 1861.

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ERRATA ET CORRIGENDA.

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Page 5, line 11 from bottom, *for* 22 *read* 2½.

„ 10, after line 5 from top *insert* Sulphate of soda...10·97.

„ „ line 8 from top, *for* 98·56 *read* 99·53.

„ 46, line 16 from bottom, *for* ramos *read* ramo.

„ 69, line 15 from bottom, *insert* n. *before* sp.

„ 125, line 8 from bottom, *for* Inzessdorfer *read* Inzersdorfer.

„ 234, line 15 from top, *for* Mr. Sharpe *read* Mr. Sharpe's paper.

„ 237, in the last note but one, *for* p. 127 *read* pp. 20, 127.

„ 358, line 17 from top, *after* But *insert* as.

„ 405, line 19 from top, *after* from *insert* the.

„ 417, line 13 from bottom, *for* blue-clay shale *read* blue clay-shale.

„ 448, line 5 from bottom (in the note), *for* in *read* on.

„ 455, last line, *for* their *read* thin.

„ 504, line 15 from top, *for* Pleuroporus *read* Pleurophorus.

„ 511, line 6 from top, *for* Straparolus *read* Straparollus.

„ 528, after the fourth paragraph, *add*,—

Whilst this paper was in the press I heard from Mr. Prestwich that in a well near Waterloo Bridge, which passed through the beds from the London Clay to the Chalk, the latter rock was found to be in a rubbly or disturbed state to a depth of at least 20 feet below the Thanet Sand.—W. W.

„ 529, line 5 from bottom, for *advantage* read *appendage.*

„ 531, last line, *dele* the ? after *Palæocrangon*; and at the end of the line *add*—*c*. Enlarged.

„ 533, line 12 from top, *for* long *read* short.

Part II.—Miscellaneous.

Page 30, line 2 from top, *for* Jonklar *read* Sonklar.

GEOLOGICAL SOCIETY OF LONDON.

ANNUAL GENERAL MEETING, FEB. 15, 1861.

REPORT OF THE COUNCIL.

In laying their Annual Report before the Geological Society of London, the Council have much pleasure in congratulating the Fellows on the generally prosperous condition of the Society.

The number of new Fellows elected during 1860 was 35, making, with four previously elected, whose fees were paid in 1860, an increase of 39. During the same year the Society has had to regret the loss by death of 19 Fellows.

One Foreign Member has been elected in lieu of one deceased. The number of extraordinary Members has been reduced by the death of one personage of Royal Blood and five Honorary Members.

The total number of the Society at the close of 1859 was 907; at the close of 1860, 922.

The excess of Expenditure over Income during 1860 has been £120 11*s.* 11*d.* This excess has been brought about by the occurrence of the following unusual items:—a donation of £50 to Mr. Nichols, the Society's late clerk, in consideration of his long services; and £100 for the additional Number of the Journal, which it was agreed to print in order to bring up arrears of publication.

The Council have to mention the handsome donation of 50 guineas by Mr. Tylor, towards defraying the general expenses of the Society.

The Funded property of the Society amounts to £4350 in Consols, besides £500 of the Greenough and Brown Bequests, invested temporarily, making in all £4850.

The Council have to announce the completion of Vol. XVI. of the Quarterly Journal, and the First Part of Vol. XVII.

A revised List of the Fellows has also been printed and circulated.

In order to aid in the re-arrangement of the Museum, a second temporary Assistant was engaged at the recommendation of the Special Museum Committee,—a step which has greatly assisted the progress reported by the Museum Committee.

The Council have to report that on the resignation of the office of Clerk by Mr. Nichols, they considered it due to his long services to present him with a sum of £50; and determined to recommend to the General Meeting to award him a further sum of £70, making up one year's salary.

A great number of Candidates having presented themselves for the post thus vacated, the Council, after a careful examination of testimonials, have bestowed the appointment on Mr. George E. Roberts.

In conclusion, the Council have to report that they have conferred the Wollaston Medal on Professor Bronn, of Heidelberg, for his long and successful labours in aiding the progress of geological science in general, and more particularly for the assistance he has afforded to the progress of Palæontology, as evidenced in his 'Index Palæontologicus,' and especially in his later work on the "Laws of the Development of the Organic World;" and the balance of the proceeds of the Wollaston Fund to M. Daubrée, of Strasbourg, to aid in the prosecution of synthetic experiments, similar to those of which he has recently given an account, and which he has intimated his intention of continuing, with the object of throwing light upon metamorphic action.

Report of the Library and Museum Committee.

Museum.

The Collections of Minerals and of Recent Shells have received but few additions; and in the latter the places of certain genera still require to be filled up.

The re-arrangement and re-naming of the British Silurian collection has been completed by Mr. Salter; and the specimens have been furnished with new tablets and labels: they now occupy 50 drawers.

The Rev. T. Wiltshire is proceeding with the arrangement of the Chalk Fossils in the Museum.

For specimens received since the last Anniversary, illustrating the geology of the British Isles, the Society is indebted especially to A. Geikie, Esq., F.G.S., J. Evans, Esq., F.G.S., and the Rev. R. Hunter; and a large collection of fossil bones from Shorncliffe, lately forwarded by the War-Department, is worthy of particular notice.

The Foreign Collection has been enriched with numerous donations, among which the Committee would especially invite the attention of the Society to a valuable series of rock-specimens from Meissen, and another from the Vosges Mountains, presented by the President: the latter series, having been carefully selected and named in accordance with the descriptions of M. Delesse, form an important typical collection. They have also to notice Mr. Bennett's Trilobites from Newfoundland, Mr. Mallet's Volcanic products from Italy, and various foreign specimens presented by Mr. Hamilton, F.G.S., the Hon. Mr. Marsham, F.G.S., Mr. Purdon, F.G.S., and the Rev. S. Hislop.

Besides the above, a suite of Norwegian rocks and minerals, a donation from His Excellency Count Platen, and a large collection of fossils from Bordeaux (named by M. Deshayes), presented by Sir Charles Lyell, deserve particular mention.

A new cabinet has been supplied for the use of the Upper Museum, as recommended by the Special Museum Committee.

Grounding their views on an elaborate and valuable catalogue prepared by Mr. Horner, of all the contributions from all countries, the Special Museum Committee, at their Meeting on the 25th of June last, resolved that the arrangement to be adopted shall be geographical, subordinate to which the fossiliferous specimens shall be in stratigraphical order, and that the non-fossiliferous and eruptive rock-specimens belonging to each geographical subdivision shall follow the fossiliferous specimens. The Committee think it their duty, in referring to this subject, to call especial attention to the continuous labour and great zeal of the President, who, in superintending the re-arrangement, has given his constant personal attendance to the details of the business, and during the past year has spent several hours of stated days in every week in actual work in the Museum.

A thorough re-ordering upon the above plan has involved a multiplicity of details in the transfer from one cabinet to another, in the rejection of useless specimens, in cleaning and labelling specimens and drawers; notwithstanding which, under the almost daily superintendence of the President, much has been accomplished in the arrangement of the European collections.

These now occupy no less than 48 cabinets, containing 336 drawers; and of their contents a very valuable and detailed catalogue has also been formed by Mr. Horner. They comprise—

1st. The geographical arrangement of the countries of Europe, with subdivisions in some—as France and Germany.

2nd. Under the head of each country, an account of the several groups of specimens belonging to it, with the names of the donors.

3rd. As the object of a geologist in examining our foreign collections may often have reference to a comparison of the rocks or fossils of different districts, columns have been prepared for references to facilitate such comparisons.

Mr. Horner's catalogues are so constructed that future contributions can be at once added under their proper heads. It is to be hoped that similar catalogues will accompany our collections from the grand divisions of Asia, Africa, North America, South America, and Australia. But the chief part, not only of the European, but also of other collections, excepting some portion named by Mr. Horner, require naming, and are on that account defective, both rock-specimens and fossils; and to this important subject the attention of the Society is invited, in the hope that some others among the Fellows, possessed of competent knowledge, will come forward to aid in enhancing the usefulness of these valuable collections.

With the view of suggesting to volunteers the examination of particular groups, as also of reminding the Fellows of the variety and extent of these collections, the following list is appended of several series of fossils in the European collections which require naming:—

Fossils in the Foreign European Collections.

Formation.		No. of Drawers.
Newer Pliocene, or Pleistocene.	*Sweden.* Uddevalla, Opslo, and Stromstadt .	3
"	*Lower Rhine.* Loess, near Bonn	1
"	*Spain and Portugal.* Gibraltar	2
Pliocene	*Belgium.* Antwerp......................	1
"	*Eastern France.* Bones from Vesoul	1
"	*Spain and Portugal.* Lisbon..............	2
"	*Sicily, Malta, and Gozo.* Palermo, &c.	8
Miocene	*Central France.* Touraine................	2
"	*Southern France.* Bordeaux..............	12
"	*Spain and Portugal.* Lisbon, &c...........	2
"	*Spain and Portugal.* Gibraltar, Alicant, Carthagena and Mula, and Totana in the Province of Murcia	5
"	*Spain and Portugal.* Granada	4
"	*Sicily, Malta, and Gozo.* Malta and Gozo ..	13
Eocene	*Belgium.* Brussels, Kunroot, Fauquemont, Limburg	4
"	*Lower Rhine.* Brown-coal, near Bonn	2
"	*Northern France.* Cassel	2
"	*Western France.* Hauteville, Dep. Manche .	1
"	*Central France.* Paris Basin	18
"	*Central France.* Bones from Auvergne	1
"	*Southern France.* Biaritz	1
"	*Spain and Portugal.* Murcia, &c.	1
"	*Northern Italy.* Monte Bolca	2
"	*Alpine Country.* Glarus, Seefeld	3
"	*Alpine Country.* Häring	2
"	*Western Germany.* Mayence	3
"	*Austria.* Santa Margarita, Neusiedel, Kronbach, &c.	1
"	*Hungary.* Buda	1
"	*Turkey in Europe.* Moldavia	1
Tertiary, undeterm.	*Southern France.* Aix in Provence	3
"	*Spain and Portugal.* Malaga, Catalonia, and Lisbon	4
"	*Sicily, Malta, and Gozo.* Sicily	6
"	*Northern Italy.* Piacenza, Turin, Bassano, Asolo and Pessagno, Tuscany, and Piedmont	13
"	*Southern Italy.* Antium, Rome, Agnano ..	3
"	*Alpine Country*	1

Fossils in the Foreign European Collections (continued).

Formation.		No. of Drawers.
Tertiary, undeterm.	*Western Germany.* Wetterau, Mayence ..	5
"	*Turkey in Europe.* Bulgaria	1
"	*Grecian Archipelago.* Candia, Eubœa	2
"	*Southern Russia.* Volhynia, Crimea	3
"	*Austria.* Vienna........................	1
Cretaceous	*Denmark.* Isle of Faxoe	1
"	*Holland.* Maestricht and Aix-la-Chapelle..	8
"	*Belgium.* Tournay, Louisberg, Kunroot, Montigny, Ciply, Konigsberg, Fauquemont, Schneeberg, &c.	9
"	*Western France.* Charante, Normandy, Cap le Hève.............................	3
"	*Central France.* Meudon, Seine et Oise	2
"	*Spain and Portugal.* Lisbon, Leira, Portugal	4
"	*Alpine Country.* Mont de Fis, Neuchatel, Tyrol	4
"	*Northern Germany.* Essen, Rheten, near Hanover, near Goslar, &c.	1
"	*Central Germany.* Dresden	1
"	*Turkey in Europe.* Bulgaria	1
"	*Southern Russia.* Volhynia	1
Wealden	*Northern Germany.* Buckerberg, Oberkirchen, Stammen......................	1
Jurassic (including Liassic).	*Northern France.* Boulonnais	1
"	*Western France.* Normandy	4
"	*Eastern France.* Besançon	1
"	*Eastern France.* Haute Saône, Sultz-les-Bains..............................	4
"	*Spain and Portugal.* Granada, New Castile, &c.................................	3
"	*Alpine Country.* Switzerland	3
"	*Southern Germany.* Bavaria	15
"	*Southern Germany.* Aalen in Würtemberg .	1
"	*Southern Germany.* Möhringen, &c.	2
Triassic	*Eastern France.* Sultz-les-Bains...........	2
"	*Central Germany.* Thuringia	1
"	*Southern Germany.* Möhringen, &c.	2
"	*Southern Germany.* Stuttgart, Baden......	2
Secondary, undet...	*Austria.* Vienna........................	1
"	*Turkey in Europe.* Dobrutcha............	1
"	*Northern Italy.* Tuscany	1
"	*Southern Italy.* Near Naples	1
"	*Southern Russia.* Crimea	1
"	*Alpine Country.* Seefeld	1
Permian	*Northern Germany.* Klein Neundorf	1
"	*Western Germany.* Wetterau	1
"	*Central Germany.* Mansfeld, Roseneck	3
Carboniferous	*Spitzbergen*	2
"	*Belgium.* Tournay......................	1
"	*Lower Rhine.* Rhenish Provinces	23

Fossils in the Foreign European Collections (continued).

Formation.		No. of Drawers.
Carboniferous	*Northern France.* Boulonnais	1
"	*Spain and Portugal.* Serra de Bussaco	1
"	*Northern Germany.* Westphalia, Harzgebirge	2
"	*Northern Russia*	3
Devonian	*Lower Rhine.* Rhenish Provinces	23
"	*Northern France.* Boulonnais	1
"	*Northern Germany.* Westphalia	1
"	*Western Germany.* Dillenberg and Wissenbach	6
Silurian	*Sweden.* Kinnekulle, Gothland	5
"	*Norway.* Christiania, Malmoe, &c.	5
"	*Lower Rhine.* Rhenish Provinces	23
"	*Western France.* Normandy	1
"	*Central France.* Angers	1
"	*Spain and Portugal.* Oporto and Bussaco ..	3
"	*Sardinia*	1
"	*Northern Germany.* Harzgerode	1
"	*Northern Germany.* Wissenbach	1
"	*Eastern Germany.* Bohemia	1
"	*Northern Russia.* Volhynia	1
Palæozoic	*Northern Italy.* Tuscany	1
"	*Southern Russia.* Crimea	1
Miscellaneous	*Central France.* Auvergne	1
"	*Alpine Country.* Tyrol	1
"	*Grecian Archipelago*	1
"	*Southern Russia*	1

Library.

Many new books and pamphlets have been acquired during the past year, both by gift and purchase. For the latter purpose £100 of the Greenough and Brown Bequest-fund were expended on various works, with which it was deemed desirable to enrich the Library. Among them may be cited Hamilton's 'Campi Phlegræi;' Waltershausen's 'Ætna' and 'Island;' Quenstedt's 'Cephalopoden,' 'Jura,' and 'Handbuch;' Eichwald's 'Lethæa Rossica;' Junghuhn's 'Java;' Kaup's 'Urweltliche Säugethiere;' Gervais's 'Paléontologie Française;' Heer's 'Tertiär-Flora der Schweiz;' and D'Alton and Burmeister's 'Gaviale'.

Many of the books and pamphlets have been bound, and with the periodicals have been placed partly in the old, and partly in the new Library-cases, which have been added in accordance with the recommendation of the Library Committee of last year.

A new alphabetical Supplemental Catalogue has been published, comprising nearly 3000 titles of books, pamphlets, and maps received in the years 1856–59, including those bequeathed by Mr. Greenough, A copy of this Catalogue has been pasted in the leaves of the reference-catalogue in the Library, and the press-marks attached. Other additions to the reference-catalogue have also been made, including an alphabetical list of periodicals. There being now three separate printed catalogues (1846, 1856, 1860), and three separate alphabetical lists in the Catalogue of Reference, it is desirable that the whole should be incorporated into one alphabetical catalogue for reference. Nearly 400 titles of books and pamphlets received or purchased during 1860 have been entered into an additional catalogue in MS. The Maps have been lately re-arranged, and a reference-catalogue completed to the end of 1859. The contents of the portfolios of Sections, Diagrams, Views, &c., have also been supervised, and catalogued in MS.

The Assistant-Secretary reports that he has received much and well-sustained assistance, chiefly in the Museum, and in preparing diagrams for the Evening Meetings, from Mr. Jenkins and Mr. Stair.

W. J. HAMILTON,
J. PRESTWICH,
J. MORRIS,
W. W. SMYTH.

Comparative Statement of the Number of the Society at the close of the years 1859 *and* 1860.

	Dec. 31, 1859.		Dec. 31, 1860.	
Compounders		120		119
Residents		200		214
Non-residents		524		531
		844		864
Honorary Members	10		5	
Foreign Members	50		50	
Personages of Royal Blood	3	63	3	58
		907		922

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years 1859 *and* 1860.

Number of Compounders, Residents, and Non-residents, December 31, 1859			844
Add Fellows elected during former years, and paid in 1860 ..	Residents .... 2 Non-residents . 2	4	
Fellows elected and paid in 1860	Residents.... 14 Non-residents 21	35	
			39
			883
Deduct Compounders deceased......................		1	
Residents ,, ...		2	
Non-residents ,, ...		16	
			19
Total number of Fellows, Dec. 31st, 1860, as above			864

Number of Honorary Members, Foreign Members, and Personages of Royal Blood, Dec. 31st, 1859 ..		63
Add Foreign Member elected during 1860..............		1
		64
Deduct Foreign Member deceased	1	
Honorary Members ,, ...	5	
		6
As above......		58

Number of Fellows liable to Annual Contribution, as Residents, at the close of 1860, *with the alterations during the year.*

Number at the close of 1859		200
Add Elected in former years, and paid in 1860........	2	
Elected and paid in 1860	14	
Non-residents who became Resident	11	
		27
		227
Deduct Deceased	2	
Became Non-resident	11	
		13
As above......		214

Deceased Fellows.

Compounders (1).

Earl Cawdor.

Residents (2).

H. G. Bowen, Esq.
Sir Charles Fellows.

Non-residents (16).

W. Anstice, Esq.
W. Atkinson, Esq.
Dr. G. Buist.
Lieut.-Gen. Sir H. E. Bunbury, Bart.
Sir A. Caldcleugh.
J. Craig, Esq.
Dr. J. G. Croker.
M. Dawes, Esq.
F. Downing, Esq.
R. G. Killaby, Esq.
F. Looney, Esq.
P. J. Martin, Esq.
Rev. Baden Powell.
Earl of Tyrconnel.
Rev. R. N. Wallace.
W. Wills, Esq.

Foreign Members (1).

Prof. J. F. L. Hausmann.

Honorary Members (5).

Dr. Emerson.
G. Hill, Esq.
Dr. Hincks.
C. Keogh, Esq.
Dr. C. Skene.

The following Persons were elected Fellows during the year 1860.

January 4th.—Stephen Harlowe Harlowe, Esq., 2 North Bank, St. John's Wood; the Rev. S. W. King, Saxlingham Rectory, near Norwich; and David Llewellin, Esq., C.E., Glyn Neath, Glamorganshire.

—— 18th.—James Poyntz McDonald, Esq., Kingsdown Parade, Bristol; William Purdon, Esq., C.E., Punjâb; and James Winter, M.D., Hampstead.

February 1st.—Thomas Pease, Esq., Westbury, Gloucestershire.

—— 29th.—William Smith, Esq., C.E., Salisbury Street, Adelphi; and C. A. Sanceau, Esq., F.C.S., Blackpool, Lancashire.

March 14th.—The Rev. T. G. Bonney, M.A., Fellow of St. John's College, Cambridge; and the Rev. Henry Eley, M.A., Broomfield Vicarage, Chelmsford.

—— 28th.—His Grace the Duke of Marlborough; and W. P. Jervis, Esq., Northwick Terrace, Maida Hill.

April 18th.—Edward Brainerd Webb, Esq., C.E., 34 Great George Street, Westminster; Spencer Herapath, 19 Sheffield Terrace, Kensington; and Owen Bowen, Esq., 4 Great Queen Street, Westminster.

May 16th.—Frederick Wollaston Hutton, Esq., Lieut. 23rd R. W. Fusileers, Royal Staff College, Sandhurst; John James Lundy, Esq., Primrose Bank, Leith; R. Farmer, Esq., the Hill, Hornsey; William Drury Lowe, Esq., Locko Park, Derby; Arthur Beevor Wynne, Esq., of the Geological Survey of Ireland; and James Wyatt, Esq., Bedford.

—— 30th.—Mark Fryar, Esq., Lecturer on Mining, &c., at the Andersonian University, Glasgow; and Francis Duncan, Esq., Lieut. R.A., Halifax.

June 13th.—George Angus, Esq., 3 Harcourt Buildings, Inner Temple; Herbert T. James, Esq., Drumkeeran, Co. Leitrim; and Henry Ward, Esq., the Oaklands, Wolverhampton.

November 7th.—William T. Blanford, Esq., of the Geological Survey of India; the Rev. Thomas Bigsby Chamberlin, Kirton in Lindsay, Lincolnshire; James Sparrow, Esq., Cymmau Hall, near Wrexham; and Richard Fort, Esq., Read Hall, Whalley, Lancashire.

—— 21st.—Major Robert Jones Garden, 63 Montagu Square; and Lieut. Robert Home, R.E., Royal Staff College, Sandhurst.

December 5th.—William Salmon, Esq., Ulverstoke, Lancashire; Peter Higson, Esq., one of H. M. Inspectors of Coal-mines, Broughton, near Manchester; John Spencer, Esq., Bowood, Wilts; Alexander R. Binnie, Esq., C.E., 7 Upper Lansdowne Terrace; George James Eustace, Esq., Arundel House, Brighton; F. D. P. Dukinfield Astley, Esq., Dukinfield, Cheshire, Arisaig, W.B., and 67 Eaton Square; and Thomas Baxter, Esq., Cathedral School, Worcester.

—— 19th.—The Rev. A. Deck, of the Royal Military College, Sandhurst; Charles Rooke, Esq., Scarborough; and the Rev. William Lister, Bushbury Vicarage, Wolverhampton.

The following Personage was elected a Foreign Member.

M. H. Milne-Edwards, Jardin des Plantes, Paris.

The following Donations to the Museum have been received since the last Anniversary.

British Specimens.

A series of thirty-six specimens of trappean rocks from Arthur's Seat, Edinburgh; presented by A. Geikie, Esq., F.G.S.

Specimens of peat and shells from Stirlingshire; presented by the Earl of Selkirk, F.G.S.

A series of plaster-casts of Cystideæ; presented by J. Mushen, Esq.

Specimens of fossil-wood from Woburn; presented by John Evans, Esq., F.G.S.

Specimens of pseudomorphs of salt in Keuper Sandstone, from Deerhurst; presented by T. R. Jones, Esq., F.G.S.

Skull of Cat in stalagmite, from a bone-cave in S. Devon; presented by C. Babbage, Esq., F.R.S.

Specimens of Corals from the Lias; presented by the Rev. P. B. Brodie.
Specimens of Fossil Ferns from Wyre Forest Coal-field; presented by Mr. George E. Roberts.
Slab of Old Red Sandstone from Mill of Ash; presented by the Rev. J. Hunter.
Specimens of Wealden Unios from Tunbridge Wells; presented by W. J. Hamilton, Esq., For. Sec. G. S.
A Collection of fossil Mammalian Bones from Folkestone; from the War-Department, through Capt. G. H. Gordon, R.E., Shorncliffe.

Foreign Specimens.

Specimens of Hollow Pebbles from the Leitha-Kalk; a suite of 156 rock-specimens illustrative of the geology of the Vosges Mountains; and specimens of Porphyries and Pitchstones from Meissen; presented by Leonard Horner, Esq., Pres. G.S.
Specimens of Paradoxides Bennettii, from Newfoundland; presented by — Bennett, Esq.
Specimens of Nemertites Strozzii from Tuscany, and some Carboniferous fossils; also a series of Tertiary fossils from Bordeaux; presented by Sir C. Lyell, V.P.G.S.
A suite of Volcanic Rocks from Italy; presented by R. Mallet, Esq., F.G.S.
Specimens of Rocks from Tuscany; Devonian fossils from the Bosphorus; Agate-specimens from Oberstein; and specimens of Opal from Königswinter; presented by W. J. Hamilton, Esq., For. Sec. G.S.
Specimens of nodules with Fish-remains from Brazil; presented by the Hon. R. Marsham, F.G.S.
Specimens of Carboniferous fossils from the Punjâb; presented by W. Purdon, Esq., F.G.S.
Specimens of Mya arenaria, from Nieue Deep, Holland; presented by J. G. Jeffreys, Esq., F.R.S.
Slab of flexible Sandstone, from Narnoul, India; presented by C. Gubbins, Esq.
A series of eighty-five specimens of rocks, minerals, and ores, from Sweden and Norway; presented by His Excellency Count Platen, Swedish Ambassador.
Specimens of Coal from Sah-Koh, Persia, collected by Mr. Mackenzie, H.M. Consul for Gilan; from the Foreign Office, by order of Lord John Russell.
Specimens of fossils, coprolites, and bones from Nagpur, India; presented by the Rev. S. Hislop.
Specimen of silicified wood from the Banda Oriental; presented by J. P. Harries, Esq.

Charts and Maps presented.

Sheet 32 (Scotland) of the Geological Survey of Great Britain; Sheets 101–112, 119–121, 128–205 (Ireland) of the Geological Survey of Great Britain; Sheet 12 (England); Sheets 107, 108, six-inch, of Lancashire; and Nos. 2, 3, 4, and 5, Horizontal Sections (England) of the Geological Survey of Great Britain; presented by the Director-General of the Survey.

Eisenbahn-Karte von Deutschland, und den angrenzenden Ländern, bearbeitet von Dr. Reden und E. von Sydow; presented by Leonard Horner, Esq., Pres. G. S.

Carte Géologique et Coupes Géologiques de la partie de Sud d'Ural Montagnes, composée par MM. Meglitzky et Antipoff; presented by the authors.

Sheet No. 1 (Melbourne) of the Geological Survey of Victoria; presented by that Survey.

Drawings, &c., presented.

A coloured print of H. B. de Saussure, and three of Glacier-travelling; presented by T. J. Laing, Esq., F.G.S.

A drawing of Cœlorhynchus rectus, and of Pristis Lathami; presented by Leonard Horner, Esq., Pres. G. S.

Two engravings of Flint-weapons found at Hoxne in Suffolk; presented by John Evans, Esq., F.G.S.

The following Lists contain the Names of the Persons and Public Bodies from whom Donations to the Library and Museum have been received since the last Anniversary, February 17, 1860.

I. List of Societies and Public Bodies from whom the Society has received Donations of Books since the last Anniversary Meeting.

Auckland. New Zealand Government.

Basel, Natural History Society of.

Berlin, Geographical Society of.

——, German Geological Society at.

——, Royal Academy of Sciences at.

Berwick. Naturalist's Field Club.

Boston (U. S.), Natural History Society of.

Bordeaux, Société Linnéenne de.

British Government.

Brussels. L'Académie Royale des Sciences.

Caen. Société Linnéenne de Normandie.

Calcutta. Geological Survey of India.

——. Bengal Asiatic Society.

Cambridge (Mass.). American Academy of Arts and Sciences.

Canadian Government.

Cassel. Natural History Society of Upper Hesse.

Cherbourg, Société des Sciences Naturelles de.

Copenhagen. Royal Danish Academy of Sciences.

Cornwall. Royal Cornwall Polytechnic Society.

Cornwall, Royal Geological Society of.
——, Royal Institution of.

Darmstadt. Geological Society of the Middle Rhine.
——, Geographical Society of.
Dublin, Geological Society of.
——, Royal Irish Academy at.

Edinburgh, Royal Society of.
——, Royal Physical Society of.

Frankfurt, Senckenberg Natural History Society of.
—— (Kentucky). Geological Survey of Kentucky.

Geneva. La Société de Physique et d'Histoire.
Glasgow Geological Society.

Halle, Society of Natural Sciences of.
——, Saxon and Thuringian Natural Society in.
Hanau. Natural History Society of the Wetterau.
Heidelberg, Natural History Society of.
Hobart Town. Royal Society of Tasmania.

India, Secretary of State for.
Iowa, Geological Survey of.
——, Government of.

Kentucky, Geological Survey of.

Lausanne. Société Vaudoise des Sciences Naturelles.
Leeds, Philosophical Society of.
Liège, La Société Royale de.
Lisbon, Royal Academy of.
Liverpool. Lancashire and Cheshire Historical Society.
——, Philosophical Society of.
London. Geological Survey of Great Britain and Ireland.
——, Royal Astronomical Society of.
London. Royal Asiatic Society of Great Britain.
——, Art Union of.
——. British Association.
——, Chemical Society of.
——. College of Surgeons of England.
——. College of Physicians of England.
——. Royal Geographical Society.
——. Geologists' Association.
——, Royal Horticultural Society of.
——. Institute of Actuaries of Great Britain and Ireland.
——. Institute of Civil Engineers.
——. International Statistical Congress.
——, Linnæan Society of.
——, Mendicity Society of.
——, Meteorological Society of.
——, Microscopical Society of.
——, Photographic Society of.
——, Royal Society of.
——. Royal Institution of Great Britain.
——. Ray Society.
——. Society for the Encouragement of the Arts.
——, Statistical Society of.
——, Zoological Society of.
——. International Association for obtaining a uniform Decimal System of Measures, Weights, and Coins.
Lyons, les Commissionnaires Hydrométriques de.

Madrid, Academy of Sciences of.
Manchester, Literary Society of.
Melbourne. Royal Society of Victoria.
——. Geological Survey of Australia.
——, Government of.
Milan, Imperial Institute of.
Montreal, Natural History Society of.
Moscow, Imperial Academy of Naturalists of.

Munich, Academy of Sciences of.

Neuchatel, la Société des Sciences Naturelles de.
New Haven (U. S.). Editor of American Journal of Science.
New York, Geographical and Statistical Society of.
——, State Library of.
New Zealand Government.

Offenbach, Natural History Society of.
Ohio, Board of Agriculture of.

Paris, l'Académie des Sciences de.
——, Dépôt Générale d'Annales des Sciences Naturelles à.
——. L'Ecole des Mines.
——. Museum d'Histoire Naturelle.
Pesth, Academy of Sciences of.
Philadelphia, Academy of Natural Sciences of.
——. American Philosophical Society.
——. American Association for the Advancement of Science.
——. Franklin Institute of Pennsylvania.
Puy-en-Velay, la Société d'Agriculture et Sciences du.

St. Louis, Academy of.

Stockholm, Academy of.
St. Petersburg, Imperial Academy of.
——, Mineralogical Society of.
Strasburg. Museum d'Histoire Naturelle.
Stuttgart. Fatherland Natural History Society of Wurtemberg.
Somersetshire, Archæological and Natural History Society of.

Toronto (Government of Canada), Public Library of.
Turin, Academy of Sciences at.
Tyneside Naturalists' Field-club.

Vienna, Geological Institute of.
——, Imperial Academy of.

United States, Government of.

Washington. Patent Office.
——. United States War Department.
——. Smithsonian Institution.
Wiesbaden. Natural History Society of the Grand Duchy of Nassau.

Yorkshire, Philosophical Society of.
—— (South). Viewers' Association.

II. List containing the names of the Persons and Public Bodies from whom Donations to the Library and Museum have been received since the last Anniversary.

Adhémar, M. G.
American Journal of Science and Art, Editor of the.
Anca, Baron.
Ansted, Prof. D. T., F.G.S.
Antipoff, M.
Athenæum Journal, Editor of the.

Babbage, C., Esq.
Bache, Prof. A. D.
Barrande, M. J., For.M.G.S.
Bennett, — Esq.
Bergh, H., Esq.
Binney, E. W., Esq., F.G.S.
Blackwall, J., Esq.
Bland, T., Esq., F.G.S.
Botfield, T., Esq., M.P., F.G.S.
Bouquet, M.
British Government.

Campiche, Dr.
Carpenter, Dr. W. B., F.G.S.
Chambers, R., Esq., F.G.S.
Chemist and Druggist, The Editor of the.
Clarke, Rev. W. B., F.G.S.
Critic, Editor of the.

Daubeny, Dr., F.G.S.
Daubrée, M. A.
Davidson, T., Esq., F.G.S.
Dawson, Dr. J. W., F.G.S.
Delesse, M., For.M.G.S.
Deslongchamps, M. E. E.
Desnoyers, M. J.
Doué, M. B. de, For.M.G.S.
Duckworth, H., Esq., F.G.S.
Duff, P., Esq.
Dulau & Co., Messrs.

Eichwald, M. E. von.
Evans, J., Esq., F.G.S.

Favre, M. A.
Forbes, J. D., Esq., F.G.S.
Forchhammer, Dr., For.M.G.S.
Foreign Office.
Forrester, J. J., Esq., F.G.S.
Francis, Dr. W., F.G.S.
Freke, Dr. H.

Gabb, M., Esq.
Gaudin, M. C. T.
Geikie, A., Esq., F.G.S.
Geinitz, Dr. H. B., For.M.G.S.
Geologist, Editor of the.
Göppert, Dr. H. R., For.M.G.S.
Gosselet, M. J.
Grant, Dr. R. E., F.G.S.
Gubbins, C., Esq.

Hamilton, W. J., Esq., For. Sec. G.S.
Harries, J. P., Esq.
Hauer, Chev. K. v.
Haven, C. H., Esq.
Hawn, F., Esq.
Hébert, M. E.
Helmersen, Col. G. v.
Henwood, W. J., Esq., F.G.S.
Hislop, Rev. S.
Hogg, J., Esq.
Holmes, F. S., Esq.
Horner, L., Esq., Pres.G.S.
Hunt, T. S., Esq.
Hunter, Rev. R.

Jeffreys, J. G., Esq.
Jeitteles, L. H.
Jervis, W. P., Esq., F.G.S.
Jones, T. R., Esq., F.G.S.

Laing, T. J., Esq., F.G.S.
Lane, C. B., Esq.
Laugel, M. A.
Lea, Dr. I.
Lindsay, Dr. W. L.
Literary Gazette, Editor of the.
London, Edinburgh, and Dublin Philosophical Magazine, Editor of the.
Longman & Co., Messrs.
Lyell, Sir C., V.P.G.S.

Mallet, R., Esq., F.G.S.
Marcou, M. J.
Marsham, The Hon. R., F.G.S.
McAndrew, R., Esq.
Mechanics' Magazine, Editor of the.
Meglitzky, M.
Meigs, Dr. J. A.
Meyer, H. von, For.M.G.S.
Mining Review, Editor of the.
Mitchell, Rev. H.
Mohrenstern, M. G. S. von.
Morris, Prof. J., F.G.S.
Morton, G. H., Esq., F.G.S.
Murchison, Sir R. I., V.P.G.S.
Mushen, J., Esq.

Newberry, J. S., Esq.
New Zealand Examiner, The Editor of the.
Nisser, P., Esq.

Oldham, Prof. T., F.G.S.
Ormerod, G. W. Esq., F.G.S.
Owen, D. D., Esq.
Owen, Prof. R., F.G.S.

Parker, W. K., Esq.
Parolini, Signor C. A.
Phillips, Prof. J., F.G.S.
Pictet, M. F. J.
Platen, His Excellency Count.
Purdon, W., Esq., F.G.S.

Quaritch, B., Esq.
Quarterly Journal of Microscopical Science, Editor of the.
Quarterly Journal of the Chemical Society, Editor of the.

Ramsay, Prof. A. C., F.G.S.
Raulin, M. V.
Readwin, T. A., Esq., F.G.S.
Reeve, L., Esq., F.G.S.
Rentzsch, Dr.
Roberts, G. E., Esq.
Roemer, Dr. F., For.M.G.S.

Scharff, Dr.
Selkirk, Earl of, F.G.S.
Shumard, F.
Silliman, Prof., For.M.G.S.
Smyth, R. B., Esq., F.G.S.
Smyth, W. W., Esq., Sec.G.S.
Sorby, H. C., Esq., F.G.S.
Steindachner, M. F.
Stoliczka, M. F.
Studer, Prof. B., For.M.G.S.
Strozzi, M. le Marquis C.
Suess, Prof. E.
Swallow, G. B., Esq.

Tate, G., Esq., F.G.S.
Tennant, Prof. J., F.G.S.
Thomson, Prof. W., F.G.S.

Verneuil, M. de, For.M.G.S.
Vivian, E., Esq.

Wallich, Dr. G. C., F.G.S.
War Department.

Zigno, Signor A. de.

List of PAPERS *read since the last Anniversary Meeting, February 17th,* 1860.

1860.
Feb. 29th.—On the Classification of the Lower Lias of the South of England, by Dr. T. Wright, F.G.S.
March 14th.—On the occurrence of the *Lingula Credneri* in the Coal-measures of Durham, by J. W. Kirkby, Esq.; communicated by T. Davidson, Esq., F.G.S.
——— On the Rocks and Minerals on the property of the Marquess of Breadalbane, in Perthshire and Argyleshire, by Carl H. G. Thost, Esq.; communicated by Prof. Nicol, F.G.S.
March 28th.—On the so-called Wealden Beds and the Reptiliferous Sandstones of Elgin, by Charles Moore, Esq., F.G.S.
——— Notes about Spitzbergen, by James Lamont, Esq., F.G.S.
April 18th.—On the presence of the London Clay in Norfolk, as proved by a Well at Yarmouth, by Joseph Prestwich, Esq., Treas. G.S.
——— On a Well in the Tertiary Sands and Clays at Bury Cross, near Gosport, by J. Pilbrow, Esq.; communicated by the President.
——— On some Foraminifera from the Triassic Clays at Chellaston, near Derby, by T. R. Jones, Esq., F.G.S., and W. K. Parker, Esq.

1860.

May 2nd.—On the Physical Relations of the Elgin Sandstones, by the Rev. W. S. Symonds, F.G.S.

———— On two newly discovered Bone-caves in Sicily; a letter from Baron Anca to Dr. Falconer, F.G.S.

May 16th.—An outline of the Geology of Venezuela and Trinidad, by G. P. Wall, Esq.; communicated by Sir R. I. Murchison, V.P.G.S.

———— On the Co-existence of Man with certain Extinct Quadrupeds, by M. E. Lartêt, For. M.G.S.

May 30th.—On certain Rocks of Miocene Age in Tuscany, by W. P. Jervis, Esq., F.G.S.

———— On the Ossiferous Caves of Gower, Glamorganshire, by Hugh Falconer, M.D., F.G.S.

June 13th.—On the Bone-caves of Gower, Glamorganshire (in continuation), by Hugh Falconer, M.D., F.G.S.; with an Appendix by Joseph Prestwich, Esq., Treas. G.S., on the Raised Beach of Mewslade Bay, and the Existence of Boulder-clay in Cefn-y-bryn.

———— On the occurrence of Crag-shells beneath the Boulder-clay of Aberdeenshire, by T. F. Jamieson, Esq.; communicated by Sir R. I. Murchison, V.P.G.S.

———— On some small Fossil Vertebræ from near Frome, in Somerset, by Professor Owen, F.G.S.

November 7th.—On the Denudation of Soft Strata, by the Rev. O. Fisher, F.G.S.

———— On an undescribed Fossil Fern from the Lower Coal-measures of Nova Scotia, by Dr. J. W. Dawson, F.G.S.

———— On the Sections of Strata exposed in the Excavations of the South High-level Sewer at Peckham and Dulwich, with Notices of the Fossils found there, by C. Rickman, Esq,; communicated by the Assistant-Secretary.

November 21st.—On the Geology of Bolivia and Southern Peru, by David Forbes, Esq., F.G.S.; with Notices of the Fossils, by Prof. Huxley, Sec. G.S., and J. W. Salter, Esq., F.G.S.

December 5th.—On the Structure of N. W. Highlands, and the Relations of the Gneiss, Red Sandstone, and Quartzites of Sutherland and Ross-shire, by Prof. James Nicol, F.G.S.

December 19th.—On the Geological Structure of the S.W. Highlands of Scotland, by T. F. Jamieson, Esq.; communicated by Sir R. I. Murchison, V.P.G.S.

———— On the Position of the Beds of the Old Red Sandstone developed in the counties of Forfar and Kincardine, by the Rev. Hugh Mitchell; communicated by the Secretary.

1861.

January 9th.—On the Stratigraphical Position of certain Liassic Corals, by the Rev. P. B. Brodie, F.G.S.

———— On the Malvern and Ledbury Tunnels on the Worcester and Hereford branch of the West Midland Railway, by the Rev. W. S. Symonds, F.G.S., and A. Lambert, Esq.

January 22nd.—On the "Chalk-rock" lying between the Lower and Upper Chalk of Wilts, Berks, &c., by W. Whitaker, Esq., F.G.S.

1861.

January 22nd.—On the gravel and boulders of the Punjâb, by J. D. Smithe, Esq.

——————On *Pteraspis Dunensis* (*Palæoteuthis Dunensis*, Roemer), by Prof. Huxley, Sec. G.S.

February 6th.—On the Altered Rocks of the Western and Central Highlands of Scotland, by Sir R. I. Murchison, V.P.G.S., and A. Geikie, Esq., F.G.S.

After the Reports had been read it was resolved,—

That they be received and entered on the minutes of the Meeting; and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved,—

1. That the thanks of the Society be given to Sir C. Lyell and Major-General Portlock, retiring from the office of Vice-President.

2. That the thanks of the Society be given to Sir P. G. Egerton, Bart., R. Godwin-Austen, Esq., W. Hopkins, Esq., and J. C. Moore, Esq., retiring from the Council.

After the Balloting-glasses had been duly closed, and the lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

Leonard Horner, Esq., F.R.S. L. & E.

VICE-PRESIDENTS.

Prof. John Morris.
Sir R. I. Murchison, G.C.St.S., F.R.S. & L.S.
Prof. John Phillips, M.A., LL.D.
G. P. Scrope, Esq., M.P., F.R.S.

SECRETARIES.

Prof. T. H. Huxley, F.R.S. & L.S.
Warington W. Smyth, Esq., M.A., F.R.S.

FOREIGN SECRETARY.

William John Hamilton, Esq., F.R.S.

TREASURER.

Joseph Prestwich, Esq., F.R.S.

COUNCIL.

John J. Bigsby, M.D.
Sir Charles Bunbury, Bart., F.R.S. & L.S.
Earl of Enniskillen, D.C.L., F.R.S.
William John Hamilton, Esq., F.R.S.
Joseph D. Hooker, M.D., F.R.S. & L.S.
Leonard Horner, Esq., F.R.S. L. & E.
Prof. T. H. Huxley, F.R.S.
John Lubbock, Esq., F.R.S. & L.S.
Sir Charles Lyell, F.R.S. & L.S.
Edward Meryon, M.D.
Prof. W. H. Miller, M.A., F.R.S.
Prof. John Morris.
Sir R. I. Murchison, G.C.St.S., F.R.S. & L.S.
Robert W. Mylne, Esq.
Prof. John Phillips, M.A., F.R.S.
Major-General Portlock, LL.D., F.R.S.
Joseph Prestwich, Esq., F.R.S.
G. P. Scrope, Esq., M.P., F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Thomas Sopwith, Esq., M.A., F.R.S.
Alfred Tylor, Esq., F.L.S.
Rev. Thomas Wiltshire, M.A.
S. P. Woodward, Esq.

LIST OF

THE FIFTY FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1831.

Date of Election.	
1808.	Professor L. A. Necker, *Geneva.*
1817.	Professor K. C. von Leonhard, *Heidelberg.*
1817.	Professor Karl von Raumer, *Munich.*
1818.	Professor G. Ch. Gmelin, *Tübingen.*
1819.	Count A. Breuner, *Vienna.*
1819.	M. Charles Lardi, *Lausanne.*
1819.	Sign. Alberto Parolini, *Bassano.*
1821.	M. Louis Cordier, *Paris.*
1822.	Count Vitiano Borromeo, *Milan.*
1823.	Professor Nils de Nordenskiöld, *Abo.*
1825.	Dr. G. Forchhammer, *Copenhagen.*
1827.	Dr. H. von Dechen, Oberberghauptmann, *Bonn.*
1827.	Herr Karl von Oeynhausen, Oberberghauptmann, *Breslau.*
1828.	M. J. M. Bertrand de Doue, *Puy-en-Velay.*
1828.	M. Léonce Elie de Beaumont, Sec. Perpétuel de l'Instit. France, For. Mem. R. S., *Paris.*
1828.	Dr. B. Silliman, *New Haven, Connecticut.*
1829.	Dr. Ami Boué, *Vienna.*
1829.	J. J. d'Omalius d'Halloy, *Namur.*
1832.	Professor Eilert Mitscherlich, For. Mem. R. S., *Berlin.*
1839.	Dr. Ch. G. Ehrenberg, For. Mem. R. S., *Berlin.*
1840.	Professor Adolphe T. Brongniart, For. Mem. R. S., *Paris.*
1840.	Professor Gustav Rose, *Berlin.*
1841.	Dr. Louis Agassiz, For. Mem. R. S., *Cambridge, Massachusetts.*
1841.	M. G. P. Deshayes, *Paris.*
1844.	Professor William Burton Rogers, *Boston, U. S.*
1844.	M. Edouard de Verneuil, *Paris.*
1847.	Dr. M. C. H. Pander, *Riga.*
1847.	M. le Vicomte A. d'Archiac, *Paris.*
1848.	James Hall, Esq., *New York.*
1850.	Professor Bernard Studer, *Berne.*
1850.	Herr Hermann von Meyer, *Frankfort on Maine.*
1851.	Professor James D. Dana, *New Haven, Connecticut.*
1851.	Professor H. G. Bronn, *Heidelberg.*
1851.	Colonel G. von Helmersen, *St. Petersburg.*
1851.	Dr. W. K. Haidinger, For. Mem. R. S., *Vienna.*
1851.	Professor Angelo Sismonda, *Turin.*

1853. Count Alexander von Keyserling, *St. Petersburg.*
1853. Professor Dr. L. G. de Koninck, *Liège.*
1854. M. Joachim Barrande, *Prague.*
1854. Professor Dr. Karl Friedrich Naumann, *Leipsic.*
1856. Professor Dr. Robert W. Bunsen, *Heidelberg.*
1857. Professor Dr. H. R. Goeppert, *Breslau.*
1857. M. E. Lartêt, *Paris.*
1857. Professor Dr. H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *St. Petersburg.*
1858. Dr. J. A. E. Deslongchamps, *Caen.*
1858. Herr Arn. Escher von der Linth, *Zurich.*
1859. M. A. Delesse, *Paris.*
1859. Professor Dr. Ferdinand Roemer, *Breslau.*
1860. Professor Dr. H. Milne-Edwards, For.Mem.R.S., *Paris.*

AWARDS OF THE WOLLASTON-MEDAL

UNDER THE CONDITIONS OF THE "DONATION-FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.,

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. L. Agassiz.
1837. Capt. P. F. Cautley. Dr. H. Falconer.
1838. Professor R. Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. M. E. de Beaumont. M. P. A. Dufrénoy.
1844. The Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. The Rev. Dr. W. Buckland.
1849. Mr. Joseph Prestwich, jun.
1850. Mr. William Hopkins.
1851. The Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. M. le Vicomte A. d'Archiac. M. E. de Verneuil.
1854. Dr. Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. Herr Hermann von Meyer. Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Prof. Dr. H. G. Bronn.

INCOME.

	£	s.	d.	£	s.	d.
Balance at Banker's, January 1, 1860	531	7	9			
Balance in Clerk's hands	9	15	2			
				541	2	11
Compositions received				110	5	0
Arrears of Admission-fees	29	8	0			
Arrears of Annual Contributions	15	15	0			
				45	3	0
Admission-fees for 1860				214	4	0
Annual Contributions for 1860....................				670	19	6
Dividends on 3 per cent. Consols				130	15	10
Publications:						
Longman and Co., for Sale of Quarterly Journal in 1859	59	1	5			
Sale of Transactions	8	11	9			
Sale of Proceedings	0	11	9			
Sale of Journal, Vols. 1–6	9	14	0			
,, Vols. 7–12	16	16	0			
,, Vols. 13–15	81	3	8			
,, Vol. 16*	123	10	9			
Sale of Geological Map	4	5	0			
Sale of Library-catalogues, including Donation from the Rev. C. Pritchard..........	5	18	6			
Sale of Alphabetical Catalogue	0	8	0			
Sale of Ormerod's Index	2	4	0			
				312	4	10
Journal-Compositions				204	0	0
				£2228	15	1

We have compared the Books and Vouchers presented to us with these Statements, and find them correct.

Feb. 2, 1861.

S. R. PATTISON, JOHN J. BIGSBY, } *Auditors.*

	£	s.	d.
* Due from Messrs. Longman and Co., in addition to the above, on Journal, Vol. XVI.	£63	12	3
Due from Fellows for Subscriptions to Journ. ..	63	8	0
Due from Authors for Corrections............	7	13	6
	£134	13	9

Year ending December 31*st*, 1860.

EXPENDITURE.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes	53	0	8			
Fire-Insurance	3	0	0			
House-Repairs	12	5	8			
Furniture	38	18	9			
Fuel	40	9	0			
Light	34	0	2			
Miscellaneous House-expenses	69	13	11			
Stationery	29	16	4			
Miscellaneous Printing	36	0	6			
Tea for Meetings	15	1	10			
				332	6	10
Salaries and Wages:						
Assistant-Secretary	200	0	0			
Clerk	108	15	0			
Assistants in Library and Museum	84	5	0			
Porter	90	0	0			
Housemaid	40	0	0			
Occasional Attendance	15	1	0			
Collector	24	5	0			
				562	6	0
Library				177	5	2
Alphabetical Supplemental Catalogue				37	5	1
Museum				43	12	6
Diagrams at Meetings				13	5	0
Miscellaneous Scientific Expenses				14	8	5
Donation (part) to Mr. Nichols				50	0	0
Publications:						
Geological Map	54	18	6			
Proceedings and Abstracts	10	7	6			
Journal, Vols. I.–VI.	0	12	8			
„ Vols. VII.–XII.	1	9	0			
„ Vols. XIII.–XV.	19	13	6			
„ Vol. XVI.	676	12	7			
				763	13	9
Invested by Treasurer out of Journal-Composition				200	0	0
Balance at Banker's, Dec. 31, 1860				19	8	10
Balance in Clerk's hands				15	3	6
				£2228	15	1

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions on Quarterly Journal account (considered good)				40	0	0
Due for Authors' Corrections				7	13	6
Arrears (See Valuation-sheet)				119	15	0
Ordinary Income for 1861 (estimated):—						
Annual Contributions, 213 Resident Fellows at 3 gs.	670	19	0			
Annual Contributions, 30 Non-resident Fellows at 1½ gs.	47	5	0			
				718	4	0
Admission-fees (supposed)				200	0	0
Compositions (supposed)				145	0	0
Dividends on 3 per Cent. Consols				131	12	0
Sale of Transactions, Proceedings, Geological Map, Library-catalogues, and Ormerod's Index				100	0	0
Sale of Quarterly Journal				200	0	0
Due by Messrs. Longman and Co. in June				63	12	3
Portion of Mr. Greenough's Bequest of £500, ordered by the Council to be sold out on account of special Expenditure incurred on Map, Library, and Museum during 1859 and 1860				200	0	0
Further amount due from expenditure incurred during 1860 in same account	106	17	3			
Special Expenditure during 1861 to be met out of the Bequest-fund	300	0	0			
				406	17	3
				£2332	14	0

JOSEPH PRESTWICH, TREAS.

Feb. 11, 1861.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes and Insurance	40	0	0			
House-Repairs .... £50 / „ special Expenditure £100	150	0	0			
Furniture	50	0	0			
Fuel	35	0	0			
Light	35	0	0			
Miscellaneous House-expenses	50	0	0			
Stationery	30	0	0			
Miscellaneous Printing, including Abstracts	40	0	0			
Tea for Meetings	30	0	0			
				460	0	0
Salaries and Wages:						
Assistant-Secretary	200	0	0			
Clerk	75	0	0			
Mr. Nichols (remainder of donation)	70	0	0			
Assistants in Library	81	0	0			
Porter	90	0	0			
Housemaid	40	0	0			
Occasional Attendants	20	0	0			
Collector	26	0	0			
				602	0	0
Library: Ordinary Expenditure	50	0	0			
„ Special Expenditure*	50	0	0			
				100	0	0
Museum: Ordinary Expenditure	50	0	0			
„ Special Expenditure*	50	0	0			
				100	0	0
Diagrams at Meetings				5	0	0
Miscellaneous Scientific Expenditure				13	0	0
Publications: Quarterly Journal	650	0	0			
„ Transactions	10	0	0			
„ Geological Map, special expenditure*	100	0	0			
				760	0	0
				£2040	0	0
Balance in favour of the Society				292	14	0
				£2332	14	0

* The "Special Expenditures" included in this Estimate refer to charges to be met out of the Greenough and Brown Bequest-fund, should the Council consider, from time to time, such expenditure advisable.

Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Banker's, 1st of January 1860, on the Wollaston Donation-fund	31	6	0	Award to Messrs. Jones and Parker	30	4	0
Dividends on the Donation-fund of £1084 1*s.* 1*d.* Red. 3 per Cents.	31	10	1	Cost of Striking Medal awarded to Mr. Searles Wood	1	2	0
				Balance at Banker's (Wollaston-fund)	31	10	1
	£62	16	1		£62	16	1

Valuation *of the Society's Property ; 31st December,* 1860.

Property.	£	s.	d.	£	s.	d.	Debts.	£	s.	d.
Due from Messrs. Longman and Co., on Journal, Vol. XVI.				63	12	3	Balance in favour of the Society	5139	1	1
Due from Subscribers to Journal				63	8	0				
Due for Authors' Corrections in Journal				7	13	6				
Balance in Banker's hands				19	8	10				
Balance in Clerk's hands				15	3	6				
Funded Property :—										
Consols, at 95	4350	0	0							
New South Wales Government 5 per cent. Bonds	500	0	0							
				4850*	0	0				
Arrears of Admission-fees (considered good)	49	18	0							
Arrears of Annual Contributions	69	17	0							
				119	15	0				
[*N.B. The value of the Mineral Collections, Library, Furniture, and stock of unsold Publications is not here included.*]										
				£5139	1	1		£5139	1	1

Jan. 29, 1861. JOSEPH PRESTWICH, *Treas.*

* This sum includes Mr. Greenough's Bequest of £500, and Mr. John Brown's of £300, both of which are invested temporarily. It has also been increased this year by the investment of £200, received on account of Journal-Compositions.

PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

15TH FEBRUARY, 1861.

AWARD OF THE WOLLASTON MEDAL.

AFTER the Report of the Council had been read, the President, LEONARD HORNER, Esq., F.R.S. L. & E., delivered to the Foreign Secretary, WILLIAM JOHN HAMILTON, Esq., F.R.S., as representative of Professor BRONN of Heidelberg, the Wollaston Medal, addressing him as follows:—

Mr. HAMILTON,—The Council have awarded the Wollaston Medal to Professor Bronn of Heidelberg, for his long-continued and successful labours in aiding the progress of geological science in general, and more particularly for the assistance he has afforded to the progress of palæontology by his 'Index Palæontologicus,' and especially by his last work, on the "Laws of Development of the Organic World."

A very wide range of subjects is embraced in his numerous publications, which extend over a period of nearly forty years. Among the earlier ones I may refer to his 'Travels in 1824–1827 in Switzerland, the South of France, and Italy,' in which many important topics of Natural History and Geology are treated of. These were followed, in 1831, by a description of the Italian tertiary formations and their fossil shells and other organic contents. I may next mention the well-known 'Lethæa Geognostica,' which has gone through three editions since 1834, and which was followed by those most useful volumes called the 'Index Palæontologicus, or Review of all known Fossil Organisms,' prepared with the co-operation of Professor Göppert of Breslau and of Hermann von Meyer of Frankfurt. The compilation of this work, however laborious, must have been beneficial, not only to the public, but to the author himself, by obliging him to study that vast store of materials on which he has since generalized with so much originality and success in several treatises on the philosophy of palæontology. It is impossible to overrate the importance of that work to the geological student, or the difficulty of its compilation, in arranging and comparing the numerous organic remains described by different persons in different places, and in giving due precedence to the numerous synonyms which have been introduced.

In relation to his theoretical speculations on the plan of creation, as deduced from geological data, and from the present state of the natural world, I may in particular advert to his treatise entitled 'Investigations of the Laws of Development of the Organic World, during the period of the Formation of the Earth's Surface,' to which a prize was awarded in the year 1857 by the French Academy,—the subjects proposed having been, "first, to examine the laws of the distribution of fossil organic bodies in the different sedimentary formations, according to the order of their superposition; secondly, to discuss the question of their successive or simultaneous appearance or disappearance; and thirdly, to inquire into the nature of the relations between the existing state of the organic world and its anterior states." In that remarkable work we are presented with a series of tabular views, exhibiting the numerical distribution of fossil genera and species, both of plants and animals, as they appear in the successive stratified formations of the earth's crust, capable of serving not only as statistical documents of the highest value to illustrate a theory of the development of life, but also as a standard to which future palæontologists may refer when they desire to know the point which their science has reached in our time. In the same work the Professor has endeavoured to show that a progressive advance towards the perfection of animal and vegetable forms and attributes has kept pace with a parallel and equally gradual improvement in the external conditions of life, or in the habitable state of the globe.

Professor Bronn supposes that there has been a passage from a thalassic and insular to a continental state of the globe, in which high mountain-chains and large areas of land separated by intervening seas have been formed, and that during those changes a contemporaneous development of the organic world has been going on, from the most simple and imperfect to the more complex and perfect—a progress equally displayed by plants and animals,—the acotyledonous, for example, having preceded the dicotyledonous plants, and the marsupial mammals of the oolite having appeared before the placental forms of the tertiary period. This relation of the continued improvement in the physical state of the earth and the concomitant changes in organic life Professor Bronn calls the *terripetal* law. Without pretending to offer any opinion on these difficult problems, to which my own studies have not been directed, I may observe that we should be lost in the contemplation of the multiplicity of facts already accumulated respecting the past history and present state of the organic and inorganic worlds, were they not presented to us in a connected view by the aid of some such bold and comprehensive theoretical speculations, which are the more interesting when we consider their bearing on Mr. Darwin's views, since published, "On the Origin of Species," which, though distinct and independent, have a close connexion with the theories which Professor Bronn has treated with so much ability.

Mr. Hamilton replied as follows:—

Mr. President,—It is with great satisfaction that I receive at your hands the Medal which has been awarded to Professor Bronn by the Council; and I shall have much pleasure in forwarding it to my learned and distinguished friend, with whom I have been intimately acquainted for many years, and whom I have always found willing to impart his information in the kindest and most liberal manner. You, Sir, have so fully expatiated on the merits of Professor Bronn, that it is unnecessary for me to occupy the time of the meeting in saying more on that subject; I shall therefore confine my observations to a brief notice of what Professor Bronn has written to me in the letters in which he requested me to receive the Medal for him.

In the first place, he has requested me to express his thanks to the Council for the great honour done to him by this award—an honour all the more remarkable in consideration of the many other distinguished individuals whose names were brought forward as candidates on this occasion. He then observes, with regret, that he has no practical field for his geological and palæontological exertions. He cannot travel and make discoveries; he has not even the use of a public collection; and he is restricted to his own means, and these are small. He trusts that, by his publication of the 'Index Palæontologicus, and 'Lethæa Geognostica,' he has given to others some assistance in prosecuting more extensive studies; and finally he observes that he has laid down the *results* of his own studies, in two works, one of which obtained the prize offered by the French Academy; the other, entitled 'The Gradual Progress of Organic Life, from the Rock Islands of the Ocean to the Continents,' is an Appendix to the "Law of the Terripetal Development of Organic Life in Geological Time," which he had established in the above-mentioned Prize Essay. I may add that, as the result of these laws, one of which is dependent on the outward conditions of existence, and the other is the effect of an independent creative force, Professor Bronn has endeavoured to show that in proportion as, first rocky islets, then groups of islands, mountain-chains, and finally large continents were raised above the level of the sea, a corresponding progression of organic life from less to more perfect forms was gradually called into existence.

In conclusion, I will only say, Sir, that, while again expressing Professor Bronn's sincere thanks for the distinguished but (as he says) unexpected honour which has been conferred upon him by the Council, I shall take the earliest opportunity of forwarding to him this mark of the Council's approbation of the eminent services which he has rendered to geological investigation.

Award of the Wollaston Donation-fund.

The President next addressed Sir Roderick Murchison, as the representative of M. Daubrée, in the following terms:—

Sir Roderick,—You are aware that the bequest of Dr. Wollaston enables the Council each year to bestow a second mark of distinction, but in another form, in order to show their sense of some valuable service rendered to geological science, and generally to aid researches in progress which involve considerable expense,—the sum at their disposal being, however, by no means a measure of the value they attach to the researches. On the present occasion, they have made this award to M. Daubrée, Dean of the Faculty of Sciences at Strasburg, Professor of Mineralogy and Geology in that Faculty, and a Chief Engineer of Mines; and I have to request that, as his personal friend, you will convey to him this testimony of the interest we take in those his researches, which have hitherto been attended with very important results.

The words of the award are these:—"to aid in the prosecution of synthetic experiments similar to those of which he has recently given an account, and which he has intimated his intention of continuing, with the object of throwing light upon metamorphic action."

But it is not only as an eminent chemical philosopher that M. Daubrée has an extensive reputation in his own and in foreign lands; he has long made valuable contributions to geology by other works. His publications date from the year 1836; since which time, besides sixteen memoirs on the analysis of minerals and other subjects of chemical geology, we have had from him a Geological Map of the Department of the Lower Rhine, accompanied by an octavo volume of 500 pages with 111 figures, descriptive of its geology and mineralogy; 'Observations on the Ancient and Modern Alluvia of a part of the Basin of the Rhine;' 'On the Erratic Phenomena in the North of Europe and the Recent Movements of the Land in Scandinavia;' 'Observations on the Quantity of Heat employed to evaporate Water at the Surface of the Globe,' and 'On the Dynamic Force of the Running Waters of the Continents;' and no less than twenty minor memoirs on miscellaneous geological subjects, succeeded by his 'Observations on Metamorphism, and Experimental Researches on some of the Agents which may have produced it;' and lastly, his important work, a copy of which he has recently presented to this Society, entitled, 'Studies and Synthetic Experiments on Metamorphism,' to which I shall have occasion to refer in the course of the address I am about to deliver.

Sir Roderick Murchison replied as follows:—

Sir,—I have listened with great satisfaction to what you have said (and so well said) in relation to the meritorious services of M. Daubrée, and I have a true satisfaction in being made the medium of transmitting to him the proceeds of the Wollaston Fund.

I am convinced that on no preceding occasion have these proceeds been awarded to a person who by his researches more completely realizes the design and object of the illustrious testator.

Seeing that M. Daubrée is continuously engaged in the prosecution of that branch of experimental science which geologists most call for, and knowing that he has already thrown great and important light on some of the most occult processes of nature in the metamorphism of rocks, I may take the liberty of saying that I hope the notice we now take of such labours may be but the prelude to our speedy enrolment of this distinguished man among the Foreign Members of the Geological Society.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

I congratulate you on the favourable position of the Society which the report from your Council has presented to you. Although we have to lament the deaths of many of our Fellows during the past year, I have not to read to you such a melancholy list as you heard from this chair at our last Anniversary, of the names of many of our associates eminent in science taken away from us in a single year; for our sorrow has been aggravated by the decease of but a few of those from whom future valuable contributions to the advancement of our science might have been looked forward to with confidence.

The Rev. Professor Baden Powell died last June, at the age of sixty-three. He took first-class honours at Oxford in 1817, became a Fellow of the Royal Society in 1824, and in 1827 was appointed Savilian Professor of Geometry in the University of Oxford, an office which he retained to the time of his death. He was elected a Fellow of this Society in 1837, and was a frequent attendant at our evening meetings; and, although chiefly known for his labours in physics, and especially in Light and Heat, he contributed much, by a variety of writings, to the general acceptance by the public of the results of geological investigations. He had worked but little at field-geology; but his unusual grasp of mind and habits of industry enabled him, whilst closely engaged in other branches of science, to keep pace with the recent observations and current literature of geology, especially on the great general questions in our science the most attractive to a philosophical mind.

The fruits of these studies were embodied in numerous articles in reviews, and in a series of works devoted, in great part, to inquiries into the relations between physical science and religion. Such were, 'The Connection of Natural and Divine Truth, 1838;' 'Essays on the Spirit of the Inductive Philosophy, &c.,' 1855; 'The Unity of Worlds and of Nature,' 1856; 'The Order of Nature," 1859. In the latter work there is a most interesting sketch of the progress of geology, from which I am tempted to quote the following admirable passage:—"The evidence of the true influence and progress of philosophical principles in this grand department of science—grand in itself, but more transcendently so in relation to the 'cosmos,' as carrying back the dominion of physical law through the abysses of past time—in its earlier stages was found where perhaps we might least have looked for it—among the Italian writers. The mantle of Galileo descended, in some measure, on Vallisneri and Moro, and more amply on Generelli, though a Carmelite monk. We here perceive perhaps the first great advance in true philosophical ideas of geology, and the anticipation and prototype of the real inductive independent views of Hutton and Lyell, under the vivifying influence of whose principles the English school of geologists is but now beginning to cast off the lingering remnants of its hereditary bondage to mystical paroxysms, occasional recurrences of chaos and creation, subversions and renewals of the order of nature, and miraculous originations of new species out of nothing—in a word, the spirit of invoking the supernatural to cover our ignorance of natural causes*."

His broad and liberal views, and his fearless assertion of the truths to which he was conducted by reasoning on facts, exposed him to the shafts of prejudice and bigotry, the more envenomed from the fact of his being himself in Holy Orders. But, although conscious that he was thereby putting a bar on his prospects of worldly advancement, he continued to the end to work steadily in the course which his conscience dictated, satisfied that at a later day justice would be rendered to his arguments. He was at the same time ever ready to give to his opponents the same credit for that sincerity of belief and honesty of purpose by which he, doubtless, felt he was himself actuated, and to which we all know he might justly have laid claim.

His lucid style, philosophical tone, and extensive learning secured for him, as a writer, the sympathy and support of the friends of intellectual progress, whilst his private friends had to admire his constant readiness to assist and instruct, his lively interest in and great acquaintance with most branches of knowledge, his skill as a musician and draughtsman, and his unassuming kindness of disposition. For many years he formed one of a small band at Oxford who kept alive the study of the physical sciences during a season when they were not regarded with so much favour as at the present day; and when, in 1850, he was appointed to be one of the Oxford University Commissioners, he had the satisfaction of aiding to introduce some of those modifications which have now given the physical sciences a recognized position in the system of studies adopted at the University.

Peter John Martin, Esq., of Pulborough, Sussex, was elected a Fellow of this Society in 1833, and died last May, aged seventy-four.

Established as a medical man in the Valley of the Arun, Mr. Martin had two favourite holiday-studies, which he continually pursued, as an antiquarian and a geologist. Of his researches in the history of the Roman Roads, and in other archæological subjects, his antiquarian friends are well aware; and accounts of them have

* Order of Nature, p. 161.

been published. Of his geological studies there are records in the Proceedings and Journal of this Society, in the 'Philosophical Magazine,' and especially in an independent memoir, published in 1838, entitled a 'Geological Memoir on a part of Western Sussex,' &c. The geological structure of the picturesque country around his residence at Pulborough early attracted Mr. Martin's attention; and, following up the labours of Sedgwick, Fitton, Webster, Mantell, and Murchison, who had already in great part elucidated the history of the Upper Secondary Rocks of Sussex, Hampshire, and the Isle of Wight, Mr. Martin was enabled to throw still more light on the nature and relations of the Chalk, Firestone, Gault, Shanklin Sand, and Weald Clay of Western Sussex. In doing this, he gave greater distinctness to the features of the "Weald Clay" than had hitherto been recognized, and he particularly drew attention to the nature of the valleys and ridges in the Wealden area, considering the valleys to have been fissures produced by the elevation and consequent fracture of the strata, and that the drainage-system of the country follows these lines of fissures to their outlets through the North and South Downs. These points are treated in detail in the memoir above alluded to, where also the effects of the derangement of strata in the production of certain valleys (valleys of elevation, &c.) are largely illustrated, comprising the phenomena of "outliers-by-protrusion," or "inliers" as they are now termed (by the Geological Surveyors); and the contemporaneous or immediately consecutive diluvian action affecting a region so disturbed was also an important subject of his consideration. The relations of the London and Hampshire basins, as trough- or basin-shaped contortions of the strata, were a favourite subject with Mr. Martin; and observations on the anticlinal line of these basins were published from time to time in the 'Philosophical Magazine.' The most elaborate of this series of 'Observations' was read before the Geological Society in 1840; but the MS. was mislaid, and not again found until 1848, three years after which it was published by its author, with additional matter, in the 'Philosophical Magazine.' It contains a large amount of information respecting the strata and lines of elevation and dislocations of the Wealden rocks, and also on the different zones of drift (gravel, pebbles, and loam) which are recognizable along the several concentric escarpments in that area, and which Mr. Martin referred to the diluvial currents consequent on the upheaval of the Wealden area.

In 1855 Mr. Martin gave the Society a note on his views of the relations of the gravels of the Sussex coast to the drift of the interior of the Wealden area, stating his belief that they belong to an outer zone of drift due to one stage of the Wealden elevation, and probably an early one.

In 1856 he still pursued his favourite researches into the nature of the diluvial phenomena of the Wealden and of the elevation and denudation of strata generally, as shown by his papers in the 'Philosophical Magazine' for 1856 and 1857; and, although failing health began to show itself, his energies were not weakened in this

his favourite study. Even in the spring of 1860 he was still engaged with this subject, and but a few days before his decease he sent a letter on raised beaches to an old friend.

Johann Friedrich Ludwig Hausmann, who was elected a Foreign Member of this Society in 1829, died at Hanover, his native town, on the 26th of December 1859, in the 78th year of his age. He had no sooner completed his academical education than he devoted himself to the prosecution of geological science. In 1807 he made a geological tour in Denmark, Norway, and Sweden; in 1809 he was placed at the head of a Government Mining Establishment in the then kingdom of Westphalia, and during his administration of it he established the School of Mines at Clausthal in the Harz Mountains. On the death, in 1811, of the celebrated Beckmann, Professor of Technology and Mining in the University of Göttingen, Hausmann was appointed his successor, with which professorship was soon afterwards conjoined that of Mineralogy and Geology, offices which he filled with unremitting zeal and with acknowledged success until within a few months of his death. During his vacations, he followed up his geological studies in England, France, Spain, and Italy. He was the author of a vast number of treatises on Mineralogy, Geology, and Technology, and held a distinguished place among the scientific men of Germany. On the death of the renowned Blumenbach, he was appointed Secretary of the Royal Academy of Sciences of Göttingen, which he continued to be to the time of his death.

It was in the year 1828 that Dr. Fitton, who had been elected the President of this Society at the preceding Anniversary, first introduced the custom of an address being delivered from the Chair at our Annual General Meetings. In the then existing circumstances of the Society, and for the next fifteen years, when a long time usually elapsed between the reading of a paper and its publication in our Transactions, a review of the proceedings of the past year was interesting and useful. But our Quarterly Journal gives so full and early* an account of the papers read, that it is now unnecessary for your President to occupy your time with such a review. I therefore propose to pass them over, and to bring under your notice some of the more prominent objects that have occupied the attention of geologists in recent times, and which must long continue to do so, while we endeavour to arrive at a true Theory of the Earth.

The Geological Survey of the United Kingdom claims, however, my first attention; for I think that, without being open to the charge of arrogance, we may say that it is an offspring of this So-

* A paper by Professor Nicol, which now occupies twenty-nine pages of our Journal, with fourteen illustrations, was read, referred, printed (the woodcuts engraved), and published between the 5th of December and the 1st of February last.

ciety. The nation is mainly indebted, for the advantages it has already and will hereafter derive from that institution, to the genius, activity, and practical judgment of one of the most accomplished geologists of the time in which he lived, and for many years a leading Member in this Society, Sir Henry De la Beche. It has, to a great extent, the same objects as we ourselves have—the promotion of geology in a strictly scientific point of view,—but with powers far exceeding any that we possess, in its numerous staff of able men devoted to the pursuit in all its branches, and with the command of extensive means supplied by Government. But it has other functions of vast importance, in the development of the mineral treasures of our country, which, until this Government School of Mines was established, was, with few exceptions, left in the hands of uneducated persons, the so-called practical men,—a system far from being yet laid aside, and in strong contrast with that of Germany and France, countries far less abounding in mineral wealth, where Schools of Mines have long existed. Such insensibility to the importance of the culture and encouragement of science on the part of our Government and the other Members of the Legislature, in a country like ours, which has had such ample experience of the benefits derived from its practical application, can only be accounted for by the physical and natural sciences having formed no part of their education. The evil effects of this absence of a just appreciation of science have of late years been considerably lessened; and there are good grounds for hoping that they will ere long entirely disappear.

My inquiries, at the Museum in Jermyn Street, as to the progress made by the Survey, and the works connected with it, during the last year, were most readily responded to by the able and zealous Director-General, and by all the gentlemen of the establishment, from whom I sought information. The contributions it has made to the science of geology, rather than to practical questions, more especially belong to this address; and most gladly would I have endeavoured to lay before you some account of them; but to do so in any intelligible manner would have led me far beyond the limits which I must observe in order to notice other subjects to which I wish to draw your attention. Among the most interesting, however, I may particularize the work commenced personally by Professor Ramsay, and afterwards accomplished, under his superintendence, by his able assistants, Mr. Geikie and Mr. Howell, in the Lothians. On two sheets of the 1-inch scale Ordnance Map are delineated the geological features, singularly varied and impressive in so limited an area, of the Silurian, Devonian, and Carboniferous strata, with the numerous varieties of felstone, porphyry, and trap, imbedded and intrusive. No one can examine those maps without feeling impatient for the publication of the memoirs explanatory of them, one of which is now in the press. There can be few districts which it would be more interesting to an experienced geologist to travel over, or one more advantageous to a learner to explore and study. I can testify to the great addition to our knowledge, theoretical and practical, which is given by these maps; and I feel assured that my old friend, Mr. Charles Maclaren, who first correctly pointed out the great geological features of the country round the Scottish metropolis, will heartily join me in applauding the results of the recent researches of the Government Surveyors.

When I inform you that during the past year accurate surveys have been made in England of 832 square miles of Tertiary and Wealden formations, 40 of Oolitic rocks, 413 of Coal-measures, Magnesian Limestone, New Red Sandstone, and Marl,—and in Scotland, 241 of Coal-measures, Old Red Sandstone, and Silurian rocks—you will readily believe that a vast mass of facts of the highest interest to geological science will be brought to light so soon as the maps, sections, and reports on those surveys are published.

Of information to be derived from publications by the Survey in the last year, we have five memoirs descriptive of coloured sheets of the Ordnance 1-inch scale Map of England, previously published; four additional coloured sheets of the same map, comprising 1700 square miles; besides four sheets of the Lancashire Coal-fields on a scale of 6 inches to a mile; and 53 miles in England, and 48 miles in Scotland of longitudinal sections, on a scale of 6 inches to the mile. Other 6-inch-scale maps of the Lancashire and Edinburgh coal-fields are nearly ready for publication.

To those who can visit the Museum in Jermyn Street, many additional opportunities for the careful study of fossils have been supplied by the labours of Professor Huxley, Mr. Salter, and Mr. Etheridge; and a second edition has been published of the very instructive descriptive catalogue of the rock-specimens, drawn up by Professor Ramsay, and, under his superintendence, by Messrs. Bristow, Bauerman, and Geikie.

The information I got at the Mining Record Office, most obligingly given to me by Mr. Robert Hunt, the keeper, relating to mineral statistics of various kinds, hardly comes within the range of our inquiries in this place. One fact I learned which was somewhat startling, namely, that the drain upon our coal-fields now amounts to 72 millions of tons per annum. Calculations have recently been made by Mr. Hull, one of the surveyors, that with an annual drain of 60 millions of tons, our coal-fields will be exhausted in a thousand years. Let us hope that our School of Mines will ascertain the existence of deep-seated beds, such as that in Nottinghamshire, made known to us by the perseverance, under great discouragements, of his Grace the Duke of Newcastle, to allay our anxiety for the fate of our remote successors.

You are probably aware that the Geological Survey of Ireland is placed under the superintendence of a Local Director, assisted by a staff of District Surveyors, and that there are distinct volumes of memoirs, with Ordnance Maps, for that part of the United Kingdom, and a Museum of Practical Geology in Dublin. Mr. Beete Jukes, the Local Director, has been so obliging as to supply me with full information respecting their proceedings in the past year.

The great features of the geology of Ireland have for some time been known by the map of Sir Richard Griffith—a rare combination of geological knowledge and persevering industry for one individual to have produced. But, with few exceptions, and those principally in the northern part of the island, little had been known of those minute details of structure which the advanced state of geology requires. The required closer examination has been for some time, and is now, in active progress, in conformity with a general plan emanating from the Director-General of the Geological Survey of the United Kingdom, worked out in its details under the superintendence of Mr. Jukes, of whose eminent fitness for the task, by scientific acquirements, experience in the field, and untiring energy, you are well aware,—aided as he is by very competent surveyors.

The Ordnance Map of Ireland, on the scale of 1 inch to a mile, is divided into 205 squares of equal dimensions; and each square will be published as a separate sheet. Of those sheets, twenty-seven geologically coloured have already been published, and twenty-one are nearly ready. Each sheet (or each small group of sheets, when it is advisable to unite them) will be accompanied by a printed explanation in 8vo form, containing, first, an account of its physical geography, showing the form of the ground, the heights of the chief points, the mean level of its plains, and the levels at which the principal rivers enter and leave, that are included in the sheet; secondly, a brief general account of the sedimentary formations and eruptive rocks, with a general sketch of the internal structure; thirdly, a sketch of the relation between the form of the ground and its internal structure; and fourthly, palæontological notes on the most remarkable fossils. After these come "Detailed Descriptions," giving an account of the observations made, the places where quarries, pits, sections, &c. may be seen, and as much of the field-notes as will guide any one who wishes to examine for himself and verify the observations of the surveyors, together with notes of the minerals, mines, drift, and bogs; and woodcut-illustrations are given with the text. There are, moreover, sheets of longitudinal and vertical sections, having only the observed data engraved. It is further intended, when all the sheets are finished, to have condensed memoirs on large districts.

In these 'Explanations' there is necessarily much repetition; but they contain so great an amount of valuable contributions to geological science in the strict meaning of the term, that, as a general work, they will well reward an attentive perusal. One of the most striking features described is the great extent of the surface that is covered by drift, its vast thickness, and the great height at which it is found in many places.

Although not connected with the Geological Survey of the United Kingdom, that now in progress in our Indian Empire is so similar in its organization, that it is to be reckoned as one of the great associations through which the sons of Britain are contributing their share to the advancement of geological science.

It is now ten years since Mr. Oldham, the Superintendent of the Geological Survey of India, arrived in Calcutta, with the excellent preparation of having been Professor of Geology in Trinity College

Dublin, and afterwards Local Director of the Geological Survey of Ireland. But so great were the difficulties with which he had to contend at the outset, and for a long time afterwards, that little more than four years have elapsed since he was able to establish that regular system of operations by which alone any sure progress could be made on a truly scientific basis. Before this, to clear the ground of difficulties and obstacles was the indispensable work. Although receiving from all in authority much support, the leading notion of the kind of work for him to do was, to go from place to place, and, without loss of time, to try to discover coal and other minerals of economic value. You are probably acquainted with the first volume of the 'Memoirs of the Geological Survey of India,' which appeared in 1859, containing nine treatises—four by Mr. Oldham himself, the others by different gentlemen attached to the Survey—accompanied by numerous maps on a large scale and many illustrations. A second volume has just been issued from the Calcutta press, containing, a memoir on the northern part of Bundelcund, by Mr. Henry Medlicott; a very extensive one on the central portion of the Nerbudda district, by Mr. Joseph Medlicott; and one by Mr. Oldham, "on the Geological Relations and probable Geological Age of Rocks in Central India and Bengal." In a letter which I received from him, dated last December, he states—"You will at once see that we have been compelled to establish several new groups to receive (provisionally) the various rocks we have had to deal with. This has been necessary as well as useful, inasmuch as for many, and these some of the most widely extended and most important groups of rocks, we had no definite horizon from which to work either up or down. Over thousands and tens of thousands of square miles we have not found a fossil,—some vegetable remains affording, at the best, imperfect evidence. The richly fossiliferous rocks of the Himalaya and Sub-himalaya are widely separated from all the rocks of the peninsula by the broad expanse of the alluvium which unites the valleys of the Ganges and Indus; and we are therefore unable to trace out any superposition."

Mr. Oldham has sent me thirty-five folio plates of the fossil flora of the Rajmahal Hills, executed in lithography in Calcutta. He was told that such work could not be executed in India; but he is not a man to be frightened by difficulties: risking a considerable personal outlay for stones, presses, and paper, he persevered, undaunted by early failures, and succeeded. Another proof of his energy is the Museum of Practical Geology in Calcutta, and the Geological Library attached to the Survey. When we consider the vast range of country over which the survey extends, and the serious obstacles to field-work in such a climate, we cannot too greatly admire the devoted zeal displayed by Mr. Oldham and the gentlemen who conduct the surveys under his superintendence. It is to be hoped that Annual Reports, such as that presented by Mr. Oldham last year, setting forth the many excellent works which cannot fail to have the most beneficial influence upon the material prosperity of the Indian Empire, will secure the zealous and liberal support of its Government. Let us also hope, for the sake of our science, that a field so sure to yield facts of the highest interest will long continue to be explored by men as worthy of confidence in their ability as those to whom the great trust is now confided.

The last year has been signalized by the publication of the remarkable work of Mr. Darwin, 'On the Origin of Species,' which has excited no ordinary degree of attention both at home and abroad. I do not presume to offer any opinion on its merits, because my previous studies have not been of a kind to qualify me to be a competent judge. But no one, however unprepared, can fail to be struck with the truly philosophic modesty and candour of the author. His acute and well-stored mind had been directed to the subject for more than twenty years, during which time he accumulated a vast mass of facts, and had carried on numerous ingenious experiments. These he has exhibited in detail before his readers, and has calmly stated the conclusions to which they have appeared to him to lead; and so far from stating those conclusions in any spirit approaching to dogmatism, he has seen and even imagined the objections which, as he himself says, might be justly urged against his theory; and in his replies he shows no desire for victory, unless won by the arms of sound reasoning. It has been observed by a critic of no ordinary power, by one eminently qualified to sit in judgment on such a work, that "all competent naturalists and physiologists, whatever their opinions as to the ultimate fate of the doctrines put forth, acknowledge that the work in which they are embodied is a solid contribution to knowledge, and inaugurates a new epoch in Natural History." The writer adds, "our object has been, in this criticism, to give an intelligible account of the established facts connected with species, and of the relation of the explanation of these facts offered by Mr. Darwin to the theoretical views held by his predecessors and his contemporaries, and, above all, to the requirements of scientific logic. We have ventured to point out that it does not as yet satisfy all these requirements; but we do not hesitate to assert that it is as superior to any preceding or contemporary hypothesis in the extent of observation and experimental basis on which it rests, in its rigorously scientific method, and in its power of explaining biological phenomena, as was the hypothesis of Copernicus to the speculations of Ptolemy. We should leave a very wrong impression on the reader's mind if we permitted him to suppose that the value of this work depends wholly on the justification of the theoretical views which it contains. On the contrary, if they were disproved tomorrow, the book would still be the best of its kind, the most compendious statement of well-sifted facts bearing on the doctrine of species that has ever appeared." If common report and intrinsic evidence are to be relied upon, the author of the above criticism is no less a person than our distinguished Secretary, Professor Huxley.

There are two chapters, however, in the work, upon which I venture to offer this opinion, that it becomes almost a duty of the President of this Society, on an occasion like the present, to recommend to the careful study of geologists. I refer to Chapter IX., "On the Imperfection of the Geological Record," and to the following chapter, "On the Geological Succession of Organic Beings." They will do well to study with great attention their valuable contents. They will there be taught a most useful lesson of the caution to be exercised in drawing conclusions from organic remains which may involve the grave questions of the age and correlation of formations; and when disposed to name an imagined new species, they will be reminded that "naturalists have no golden rule by which to distinguish species and varieties," and they will learn to pause until they feel assured that no sources of mistake have been overlooked.

It would be both useful and interesting if the annual Presidential Address were to contain a summary of the most prominent geological memoirs contained in the Transactions and Journals of foreign countries; but the field over which the researches in geology now extend is so vast, that it is beyond the power of any individual to give even a brief sketch of the labours, in a single year, of its more eminent foreign cultivators. Were the limits within which an address of this kind ought to be confined in itself no obstacle, there is the manifest impossibility for any one individual to possess that acquaintance with what has been done in the past year in chemistry, mineralogy, physics, botany, and zoology, which would enable him to touch upon even the salient points in those branches which bear upon our science; and, as you are aware, geology lays every one of them under contribution. But although a review of our own proceedings be unnecessary, and a summary of the labours of foreign cultivators of natural science be impracticable, our annual meetings are fit occasions for calling the attention of our Fellows to some of the more important subjects which have more recently occupied the attention of geologists. Among those, the researches in what may appropriately be called Chemical Geology occupy a prominent place.

The application of chemistry to the explanation of geological phenomena has hitherto received more attention on the continent than with us. The greater features of the earth's structure and palæontology in its various branches have, with few exceptions, been the chief study of British geologists. When organic remains no longer present themselves in the older formations, or are nearly obliterated in the newer, the term *metamorphic* has become very current; but the origin of metamorphism (that is, the exciting causes of the molecular actions by which it could have been brought about in accordance with known chemical laws) has rarely been a subject of investigation with us. Metamorphism must, in every case, be the result of chemical action; and we can only arrive at a just conception of the processes by which the various forms under which it presents itself could have been produced, by illustrations afforded by experiments in the laboratory, under the guidance of an accurate acquaintance with chemical agencies and the laws of combination among mineral elements. So also it is only by the same safe guidance that we can hope to arrive at a right knowledge of the nature of the eruptive rocks, of the changes which nearly all the stratified rocks, of all ages, have more or less undergone since their constituent detrital parts were first deposited, whereby loose mud and sand have been converted into hard and often crystalline rocks, of the formation of the accessory simple minerals which many of the strata include, and of the complex phenomena of mineral veins. In the whole range of palæontology even, there is scarcely a single organism that exists in its pristine state; neither shell, bone, nor plant remains in the condition it was when first entombed. The great problem, by what process vegetable matter has been converted into bituminous coal, is still unsolved. Not only in early times, but even at no distant period, it has not been uncommon for geologists to build up theories by invoking the aid of chemical solutions and vapours, without even an attempt to show that such agencies were even possible. It will doubtless be ever impossible for us to subject substances to operations in our laboratories more than resembling in kind those which we suppose them to have undergone in the interior of the earth, in order to produce metamorphism, or to form eruptive rocks and mineral veins; we can never know the effect of processes continuing under enormous pressure for thousands of years; but we may obtain results, on a small scale, so closely resembling, indeed often identical in composition and form, natural productions, as to entitle us to infer that the processes of nature have been analogous to those which we have employed.

The celebrated experiments of Sir James Hall, more than half a century ago, on the effects of heat modified by compression, may be said to have formed an epoch in the history of theories of the earth. They were undertaken for the purpose of testing the soundness of the theory advanced by Hutton, that rocks, including limestone, had been consolidated by the effect of heat under powerful compression, which he had been accustomed to discuss with that illustrious philosopher. Hall, then a young man, was not convinced by the arguments of his master in geology, and especially as they applied to carbonate of lime, a substance, which, as he said, every limekiln showed to be changed in its nature by heat. But fearing that the results of the experiments he was contemplating would not confirm the bold hypothesis, from tenderness for the then declining health of the amiable old man, he postponed them until after his death in 1797. He was patient in his researches; for they were carried on for several years, and amounted, as he states, to the large number of 156. He was no less cautious in drawing his conclusions; for, although the results he was obtaining were known to Playfair and his other geological friends, he first made them known to the public by his memoir read before the Royal Society of Edinburgh on the 5th of June, 1805. His experiments, though varied in form, were similar in kind. He subjected finely pulverized common limestone, sometimes pulverized calcareous spar, enclosed in gun-barrels or in tubes bored in masses of wrought-iron, firmly pressed down and hermetically sealed, in a furnace to an intense heat. With regard to the pressure, Sir James Hall states that he tried various amounts:

52 atmospheres, equal to 1700 feet of sea; 86, answering to nearly 3000 feet; and 173, to 5700 feet of sea—that is, a little more than a mile. The results were, that under the first of these pressures the powder was changed into a compact limestone, under the second to a marble, and under the last it underwent complete fusion, and acted powerfully on other rocks. He states that on exhibiting a specimen of the saccharoid marble to the workman he employed to polish it, the man observed that, if it were a little whiter, the quarry from which it had been taken would be of great value.

The soundness of the conclusions to which Hall arrived has been lately called in question by Dr. Gustav Rose, Professor of Geology in the University of Berlin, in a memoir published in the 'Monatsbericht' of the Berlin Academy for July last, giving an account of two experiments on the effect of a powerful heat on earthy limestone enclosed in a gun-barrel hermetically sealed,—experiments so far analogous to some of those of Sir James Hall. The barrel was placed in a newly erected gas-furnace, in which the heat was sufficiently great to melt easily large masses of platina. He describes the changes which the earthy limestone was found to have undergone, and thus concludes:—"From these experiments it would appear that chalk and compact limestone, when subjected to a high temperature in a closed space, are not changed into distinct crystalline spar, and that, as a general fact, rhomboidal carbonate of lime is not formed by the so-called dry process. When the descriptions of Hall's experiments, as well as those which Bucholz afterwards made with the same object, are examined, it appears extremely probable that the results were what the authors describe, but that they mistook the hard-baked but unaltered chalk for crystalline marble. Although those experiments of Hall have been so much quoted, as affording an explanation of geological phenomena, and in support of theoretical views, they have not received any confirmation from having been repeated by others; and the experiments of the present author show how hasty the general conclusions were which were drawn from them."

With every respect for my friend the Professor, I think that I may turn round upon him and say that *he* has been somewhat hasty in considering that his experiments prove that mistakes were made by Hall in his descriptions of the results of his numerous experiments, all agreeing while obtained in so many different ways; for the Professor states that in both of his experiments the gun-barrel burst (at what stage of the experiment, he does not say); and thus one of the essential conditions in Hall's experiments was wanting, viz. continued great pressure. I consider therefore that these experiments of Professor Rose in no degree invalidate those of Hall, so long considered to support, in no inconsiderable degree, the hypothesis of Hutton.

In 1816 Professor Hausmann of Göttingen drew attention to the explanation of geological phenomena by observations on some products obtained from smelting-furnaces. Among the most remarkable results of the condensation of the vapours of smelting-furnaces is the formation of crystals of felspar, which have been frequently found in the copper-works of Mansfeld—the more remarkable as all attempts to obtain them by direct fusion have hitherto failed. The first direct synthetic experiments to obtain minerals artificially by igneous fusion were made successfully by Berthier, followed in 1823 by Mitscherlich. They obtained many crystallized simple minerals identical with those of nature. These researches for a long time led to the belief that fluidity by heat could alone have yielded such results; but within the last few years, and especially within a short time, other researches have produced a conviction that *water*, combined with heat and pressure, must have acted a very important part in most of the operations ascribed to the action of heat and pressure only, from the earliest periods of geological time.

That an enormous pressure must take effect, even at moderate depths, is self-evident; and that a very high temperature prevails in the interior of the earth is proved by the existence of volcanos in all parts of the earth, which from time to time pour forth streams of molten incandescent rock; and that a heat sufficient to keep rocks in a fused or viscid state has existed from the earliest geological time is made manifest by the veins and intruding masses of granite and the other eruptive rocks that penetrate all formations, from the oldest to the newest strata; for the cone of trap that traverses the Carboniferous rock and rises to the summit of Arthur's Seat, Edinburgh, is now believed to be of tertiary age. That this internal heat is permanent is further demonstrated by the increase of temperature as we descend from a short distance below the surface, in all parts of the earth where the experiment has been made. We have thus undoubted proof of the existence of two of the three great active agents in the laboratory of nature, heat and pressure.

Without assuming the existence of great internal supplies of water or its elements, there can be no doubt that it must exist in the interior of the earth to a vast extent. The amount of that which is carried off by rivers must bear a small proportion to that which, falling from the atmosphere upon the wide-extended surface of the land, must be carried to great depths through porous rocks, and by the innumerable cracks and fissures by which every rock is more or less traversed. The existence of subterranean rivers and of accumulations of water at great depths is proved by artesian wells; and, as we know no limits to the downward extent of faults and fissures, there is every probability that much of the water that falls on the surface must penetrate to depths where a high temperature exists; as is shown by hot springs, the temperature of which we know to have continued undiminished for centuries, and by the enormous volumes of watery vapour poured forth by volcanos. It probably reaches depths where the heat will bring it not only to the boiling-point, but, under great pressure, to a far higher temperature. According to the researches of Mr. Robert Hunt, the rate of increase of temperature, from about 100 feet below the surface, is 1° of Fahr. for every 50 feet in penetrating through the first 100 fathoms; 1° for every 70 feet in the next 100 fathoms; but when the depth exceeds 200 fathoms, the increase is only 1° for every 85 feet of depth*. Supposing the increase for greater depths to be at the average rate of 1° for every 100 feet, the temperature of the melting-point of cast-iron, viz. 2786° of Fahr.†, will exist at a depth of somewhat less than $44\frac{1}{2}$ miles, that is $\frac{1}{88}$th of the earth's equatorial radius. A cubic inch of water at 212° expands to nearly a cubic foot of steam, or, more accurately, to 1696 times its volume. By an addition of the pressure of one atmosphere, the mercury standing at 30 inches, the boiling-point is raised from 212° to 249°; and by continuing the heat, without allowing the steam to escape, the boiling-point rises still higher; and the elasticity of the steam increases with increasing rapidity as the temperature rises. By the experiments of Regnault, it has been shown that by a pressure of

2	atmospheres,	the boiling-point	is	249°·5
3	,,	,,	,,	273·3
4	,,	,,	,,	291·2
5	,,	,,	,,	306·0
10	,,	,,	,,	356·6
20	,,	,,	,,	415·4

As the temperature rises by equal additions of heat, the increase of elasticity is more rapid at high than at low temperatures. But it is only when in contact with a body of water from which fresh steam is constantly rising that the elasticity augments in this manner, and thus produces a force sufficient to rend asunder the strongest vessels. If dry steam alone be heated, it follows the law which regulates the expansion and elasticity of gaseous bodies in general‡. Thus, independently of the action of water as a constituent of mineral substances, we may, with every degree of probability, consider high-pressure steam to have been the power which rent, shattered, and elevated the sedimentary strata in all geological periods, which drove the softer granites and trappean rocks into rents, and protruded them to the surface, producing the jagged fractures of the upheaved strata—that evident snapping of a hard substance, leaving splintered ends and edges. "In the Alps of Switzerland and Savoy, we find the most stupendous monuments of mechanical violence, by which strata thousands of feet thick have been bent, folded, and overturned, marine secondary formations upheaved to the height of 12,000, and some eocene strata to 10,000 feet above the level of the sea§." To what more probable agency than that of high-pressure steam can we ascribe such effects?

The powerful part which water has played in the formation of minerals and rocks is shown in a very clear manner by Professor Gustav Bischof of Bonn, in his elaborate 'Lehrbuch der Chemischen und Physikalischen Geologie,' in four 8vo volumes, the first published in 1847, the last in 1855, showing a vast amount of indomitable

* Sorby, Quarterly Journal of Geological Society, vol. xiv. p. 495.
† Miller's Chemistry, vol. i. p. 194. ‡ *Ib.* vol. i. p. 250.
§ Lyell, Manual of Geology, 5th ed., p. 621.

perseverance in laborious research so peculiarly characteristic of his countrymen. His recorded experiments extend over a period of more than thirty years. His ' Lehrbuch,' even in the English translation in a condensed form (executed with the cooperation of the author, under the auspices of the Cavendish Society), does not appear to have received from the geologists of this country a due attention, while he is constantly referred to as a high authority by the most eminent geologists of France and Germany.

The agency of water in the formation of minerals was shown nearly forty years ago by Becquerel, who succeeded in obtaining by a humid process galena, sulphuret of antimony, and other minerals occurring in veins. M. Scheerer*, in an elaborate memoir on the plutonic nature of granite, in 1846, on a review of the chemical and mechanical constitution of that rock, and of the many accessory minerals it often contains, and especially their different degrees of fusibility and the different temperatures at which they crystallize, arrived at the conclusion that the various phenomena they exhibit, as simple minerals and in combination as a rock, can only be explained by the combined action of heat and water. He tells us that he began to study the granitic rocks of Norway in 1833, fully impressed with a belief in the plutonic (that is, the solely igneous) origin of granite, but that the result of a most careful research was an entire overthrow of his early creed, and that "l'idée la plus juste que l'on peut se former sur l'origine de ces roches est celle qui attribuerait aux deux éléments, à l'eau et au feu, une égale puissance créatrice." M. Elie de Beaumont, in 1847, in his very instructive essay "Sur les émanations volcaniques et métallifères," brings forward numerous instances which appear to him to prove the existence of water in the constitution of eruptive rocks and mineral veins. Thus, while the igneous fusion of granite is, in his opinion, proved beyond all doubt by many phenomena that accompany it, he considers it to be no less capable of proof that water must have entered into its composition while in that state. He observes that M. Scheerer of Christiania has given many reasons why granite in fusion must have contained water, that it was in combination with it at the time of its eruption, and that it was retained until after the final cooling of the granite; for many simple minerals containing water as a constituent are found in that rock. M. de Beaumont conceives that there is, in truth, no reason against believing that granite contained water at the time of its eruption; for the lavas of existing volcanos, at the time of their ejection, contain a large amount of water, which in part separates in the form of vapour, but is not entirely dissipated for many years†. In treating of different kinds of

* Bulletin de la Soc. Géol. de France, 2de série, vol. iv. p. 468.

† "Dans les exhalaisons volcaniques, il est un corps qui n'a pas tout d'abord fixé l'attention, parce que, sous l'empire des idées anciennes, il semblait tout à fait inerte, surtout en présence des minéraux dont il s'agit d'expliquer la formation, mais auquel pourtant le premier rôle paraît devoir être dévolu, dans les phénomènes métamorphiques aussi bien que dans les éruptions des volcans: ce corps c'est l'eau, qui se trouve dans ces exhalaisons, non en quantité minime, comme les vapeurs, mais, au contraire, comme le produit à la fois le plus abondant

quartz, he states that it is probable that water has played a part in the formation of all of them*.

The powerful action of water at a high temperature, under great pressure, upon mineral substances has been recently most satisfactorily proved by the synthetic experiments of M. Daubrée†. In stating the object of his researches, he observes—"No one is unacquainted with the results obtained long ago by Berthier and Mitscherlich, and more recently by Ebelmen, regarding the formation of silicates at high temperatures by means of fusion. Thus, while *the dry process* yielded by various methods crystallized anhydrous silicates, some of which are identical with those found in metamorphic rocks, it had hitherto been found impossible to obtain similar imitations by the *humid process*. Synthetic experiments, guided by geological induction, could alone solve the question. Such is the aim of those in which I have endeavoured to bring into play affinities capable of producing like combinations." He enclosed the minerals he operated upon in a glass tube partially filled with water, which he inserted in a strong iron tube, between which and the glass tube water was poured, to counterbalance the tension of the vapour in the glass tube, which would have caused it to burst. The iron tube being firmly closed by a screw, was placed in a bed of charcoal powder, and exposed for several weeks to the heat of a gas-making furnace, in which the heat could not be less than 850° Fahr., and when taken out was allowed to cool gradually. With all the precautions he could take, so great was the tension of the vapour, that, of the many experiments, two tubes out of three exploded.

After being exposed to the heat of the furnace for a week, the structure of the glass was no longer recognizable. It was entirely changed into a white substance, perfectly opake, and adhering to the tongue, exactly resembling kaolin. In some of the experiments the form of the tube was preserved, but in others the glass was reduced to a white powder. Entirely new combinations had been formed: the water had become highly charged with an alkaline silicate; and the opake substance, which at first sight had appeared amorphous, was found to be entirely composed of crystalline elements. They were seen, even without the aid of a magnifying glass, to consist of limpid colourless crystals, having the ordinary bipyramidal form of quartz and its usual appearance; they were, in fact, no other than crystallized

et plus constant des éruptions, dans toutes les régions du globe. La singulière propriété que possèdent les silicates incandescents des laves de retenir pendant fort longtemps, et jusqu'au moment de leur solidification, des quantités d'eau considérables, démontre clairement que l'action de la chaleur n'exclut pas celle de l'eau, et paraît annoncer que cette dernière a, même à ces hautes températures, une certaine affinité pour les silicates. Nous ne connaissons des masses situées à une certaine profondeur dans notre globe que ce qu'en apportent les volcans: or ces déjections renferment toutes, sans exception, de l'eau, soit combinée, soit mélangée; nous sommes donc en droit de penser que l'eau joue un rôle tout à fait important dans les principaux phénomènes qui émanent des profondeurs."—*Daubrée, Etudes et Expériences Synthétiques sur le Métamorphisme*, p. 85.

* Bulletin de la Société Géologique de France, 2de série, vol. iv. p. 1249.

† Observations sur le métamorphisme, et recherches expérimentales sur quelques uns des agents qui ont pu le produire.

silica. Some crystals formed in this way, at the end of a month, attained the size of two millimetres (=·07874 inch). They were often insulated in an opake paste, sometimes adhering to the sides of the tube, forming true geodes, impossible to distinguish, except in size, from those which crystalline schists often contain. The white substance which forms the greater part of the residue of the transformation of the glass is not amorphous, but forms acicular crystals which cannot be better compared than to the dust of fibrous hornblende passing into asbestus. They proved on analysis to be composed of constituents nearly identical with wollastonite. M. Daubrée adds, "It is impossible to look without astonishment upon so complete a change in the physical and chemical condition of glass obtained by a very small quantity of water, in weight not exceeding one-half of that of the glass so transformed." Under the same conditions, moreover, water exerts an influence on crystallization of the most remarkable kind on quartz and the silicates. At a temperature of about 850° it dissolved the elements that had been combined in the glass by a much more powerful heat, but without its intervention. Its vapour, under the conditions of the experiments, by reason of its acquired temperature and density, acts chemically like water in the fluid state.

In the presidential address of my predecessor, Professor Phillips, in 1859, mention is made of the observations of M. Daubrée, of Strasbourg, on the hot springs of Plombières, then recently made known; and I now recur to them in greater detail because of their important bearing on the subject to which I am now endeavouring to call your earnest attention, namely, the increasing conviction on the minds of geologists, produced by experiments in the laboratory, that water must have played a most important part in the origin of simple minerals, of the eruptive rocks, and in metamorphic action. M. Daubrée made the experiments above described with the water of those springs concentrated to a twentieth of its volume, and he also made a careful examination of their effects upon the mineral substances over which they flow. They rise on the south-west flank of the Vosges Mountains, and issue from a porphyritic granite,—the temperature of the hottest being 78° C. (=172$\frac{1}{4}$° F.), and others from 15° to 30° C. (=59° to 86° F.). They contain only a minute quantity of saline matter, not more than *half a grain* to the quart; but silicate of potash predominates. The Romans had formed in it a thick mass of concrete, with channels or gutters, to convey the water to the baths which they constructed in that place, and which still exist. It is composed partly of bricks and partly of the neighbouring bunter-sandstein, united by a mortar of lime without sand. This concrete is about 10 feet thick; and M. Daubrée found that the water has filtered through the crevices of the mortar in a continuous stream. The calcareous cement and even the bricks themselves have been partially metamorphosed. The new combinations produced are found especially in the cavities of the mass, where they form mammillary concretions, sometimes crystallized. The most remarkable of these in point of number are silicates of the zeolite family, and particularly apophyllite and chabasie*. Besides these, there are some other zeolites, together with opal, mammillary hyalite (perfectly transparent and undistinguishable from the hyalite of basalts), aragonite, and calcareous spar. The apophyllite is found only in the cavities of the mortar; it is a silicate containing lime and potash; whereas the chabasie, a double silicate of alumina and potash, occurs exclusively in cavities of the brick. The neighbouring granite has never been found to contain any zeolites; but the water contains the elements of that family of minerals, potash and lime, the former being derived from the decomposition of the felspar of the granite, the latter from the mortar. Thus it appears that minerals which we find in veins and in eruptive rocks may be formed by the joint agency of water and heat, although that heat may not exceed 158° F. In prosecuting these experiments, M. Daubrée obtained well-formed crystals of the transparent variety of augite, called diopside. Fir-wood was changed into a black compact shining body, having all the appearance of pure anthracite, and so hard as to be scratched with difficulty by a steel point. It closely resembles the anthracite that accompanies veins of silver in gneiss at Kongsberg in Norway.

I have said that the experiments of Sir James Hall formed an epoch in the history of theories of the earth. In the same light, but in a still higher degree, the observations and synthetic experiments of M. Daubrée, showing the powerful and widely extended agency of water, will probably be viewed as an epoch in our science. He has demonstrated that water, accompanied by heat and compression, with a very minute quantity of potash, has a solvent power upon a wide range of mineral substances, especially upon silica, the earth of all others the most prevalent in the structure of the globe. He has further proved that the degree of heat imagined to be necessary for the production of certain minerals has been much exaggerated, and that products characteristic of metallic veins and volcanic rocks may be formed at a temperature not exceeding 158° F. He refers especially to the zeolite family so constantly found in trappean and volcanic rocks, both as a constituent part, and as filling vesicles, and which, therefore, may have been formed when the process of cooling had been far advanced. He reminds us that zeolites have been found in the fragments of tertiary limestone that occur in the basaltic tuff of the Puy de la Piquette in Auvergne. He has further shown that the molecular state of the water in lavas, be it what it may, has had a great effect in the formation of silicates, even when anhydrous. It causes them to separate, and to crystallize at a temperature much below their point of fusion; it enables them to crystallize in an order of succession different from that of their fusibility: thus, for example, leucite, an infusible silicate of alumina and potash, occurs in lavas in well-formed crystals, often of large size. To this, Ludwig, in his German translation of Daubrée's essay, adds that the crystals of leucite often contain fragments of lava, and even small

* In sixteen different species of zeolite, water has been found to enter largely into the composition of each, varying from 8 per cent. in some specimens of analcime, to nearly 22 per cent. in some specimens of chabasie.

crystals of the very fusible mineral augite. There is an important remark of Daubrée, that, at high temperatures, so small a quantity of water is sufficient to produce crystallization of silicates, that that existing in clays, or even that mechanically contained in rocks, commonly termed the water of the quarry (*eau de carrière*), appears to be all that is required to develope, when assisted by heat, very energetic action.

Metamorphism.

The term "metamorphic" was first given by Sir Charles Lyell in 1833, as a designation for certain of the older strata considered to have been altered by subterranean heat. He states, in the last edition of his 'Manual of Geology,' that by metamorphism he means an action, existing in the interior of the earth at an unknown depth, whether thermal, hydrothermal, electrical, or other, analogous to that exerted near intruding masses of granite, which has, in the course of vast and indefinite periods, and, when rising perhaps from a large heated surface, reduced strata thousands of yards thick to a state of semifusion, so that on cooling they have become crystalline like gneiss. He enumerates as the principal metamorphic rocks—gneiss, mica-schist, hornblende-schist, clay-slate, chlorite-slate, hypogene-limestone, and certain kinds of quartzite. These rocks, he says, when in their most characteristic and normal state, are wholly devoid of organic remains, and contain no distinct fragments of other rocks, whether rounded or angular, and that, however crystalline they may become in certain regions, they never, like granite or trap, send veins into contiguous formations, whether into an older schist or granite, or into a set of newer fossiliferous strata. Here then we have the term distinctly conjoined with a theory of the agency by which the metamorphism is produced, and an equally distinct restriction of the term to particular rocks.

But such a restriction is now disregarded both in this country and elsewhere, and the term metamorphic is applied to any sedimentary rock, secondary or tertiary, which is altered from its original state to a hardened or crystalline structure, without reference to any theory of the agency by which the change was produced, however diversified the nature of the rock may be. Thus, M. Coquand, in his 'Traité des Roches,' published in 1857, has a whole family of *Roches métamorphiques*, comprising thirteen species and no less than eighty-eight varieties, as follows:—

Mica-schiste, embracing	... 11	varieties.	Gypse, embracing	 7	varieties.
Talc-schiste ,,	... 10	,,	Anhydrite ,,	 2	,,
Chlorite-schiste ,,	... 5	,,	Alaunite ,,	 5	,,
Amphibolite-schiste ,,	... 5	,,	Quartzite ,,	 5	,,
Argiloschiste ,,	... 9	,,	Jaspe ,,	 5	,,
Calcaire ,,	... 12	,,	Porcellanite ,,	 6	,,
Dolomie ,,	... 6	,,			

Taken in its widest sense, the term might be applied to every altered rock, be its age what it may; for a structural change is as distinct in many sandstones and limestones as in the older strata. Studer and Merian found in the Alps of Glarus the flysch passing into rocks as crystalline as the mica-schist and gneiss of St. Gothard and Chamouny; and Sir R. Murchison has shown that large portions of the flysch in the Grisons have been converted into a crystalline rock, and that in many places in the Alps, secondary and even tertiary limestones are changed into saccharoid marble undistinguishable from that which has been called primary.

But it is obvious that the metamorphism of materials so very different in their nature cannot have been brought about except by very different chemical operations, and that it could not have been produced in all by the materials having been exposed to a deep-seated internal heat; for the altered rocks alternate with others of vast thickness which have undergone no change, and through which the heat could not have been transmitted. It is nevertheless very doubtful whether the term is ever applied without some vague, indistinct belief that internal heat has been the great agent in the change; this certainly is not a very philosophical state of mind, and shows how much it behoves us to be cautious in the use of a term involving theory unsupported by experimental proof. To the fact of the change of structure we cannot shut our eyes; it is plain and palpable; and we must give it a name; but the name should be free from any unproved theoretical import. No true theory of the earth can be arrived at until the theory of metamorphism, in its various phases, has been established on sound chemical principles by synthetic experiments.

I have already referred to the memoir of M. Daubrée on Metamorphism, published in 1858. In the same year there appeared the 'Études sur la Métamorphisme' of M. Delesse. He truly observes, at the very outset of his work, that "metamorphism comprehends phenomena which are extremely complex, and which are for the most part involved in great obscurity." He considers that the subject is divisible into two distinct forms,—the one being *normal* or *general* metamorphism, the result of causes most frequently invisible, and which have operated on a great scale; the other *abnormal*, or rather *special*, metamorphism, the result of accidental causes, the effects of which are of limited extent. It is to this last form, which he also designates "metamorphism of contact," that this publication is confined. But there can be no doubt that normal or general metamorphism is by much the most important subject for our careful study: that of contact is only a subordinate branch of the great question. Researches and experiments relative to it are doubtless of great value as *indications* of the causes of the greater operation, and as likely to lead to some well-founded theory of the many phenomena of general metamorphism. But the processes, whatever they were, must have been very different which caused the alterations produced, on many occasions, when an eruptive and a stratified rock came in contact, and that transformation which has extended over thousands of square miles. In the former case the rock affected and that affecting are before us, and the change was probably the work of a comparatively short time; while in the latter case all is hidden, and the operation was, with greater probability, the slow continuous effect of thousands of years of chemical action under enormous pressure.

M. Delesse has very recently presented us with another work in which the larger subject is treated of with great minuteness of detail, and in which he has brought to bear his extensive observations, his mineralogical knowledge, and his skill and experience in chemical analysis. He has been so obliging as to send me an unpublished copy of his memoir, which, consisting of 90 quarto pages, will form a part of a forthcoming volume of the 'Mémoires de l'Institut de France.' In this work he by no means confines the term metamorphism to those rocks to which it was originally applied by Lyell, and to which it is restricted by many geologists, but gives it a very wide range. He says at the very outset, "Toutes les roches qui entrent dans la composition de l'écorce terrestre ont pu être modifiées par le métamorphisme général" (p. 129); that "il est bien constaté maintenant que les roches métamorphiques se sont formeés à toutes les époques géologiques" (p. 152). He speaks of "roches métamorphiques appartenant à tous les terrains, depuis le silurien jusqu'au nummulitique" (p. 155). He considers that the formation of coal in all its varieties, from lignite to anthracite, is the result of general metamorphism: "Le métamorphisme général subi par les combustibles est identique à celui qui est éprouvé au contact de roches non-volcaniques" (p. 160). It is evident, therefore, that metamorphic action, in the sense in which it is used by M. Delesse in this memoir, becomes nothing more than a general term for that agency or variety of agencies by which mineral substances have undergone alterations from their original state throughout all geological periods, and is the abandonment of a very convenient technical designation for a particular class of rocks—those inferior basic rocks which have been held to have been for the most part transformed from a prior condition of sedimentary deposits.

On the 30th of last June, the Academy of Sciences of Paris awarded to M. Daubrée the Bordin Prize for an essay entitled "Études et Expériences synthétiques sur le Métamorphisme et sur la formation des roches cristallines," which has since been published. He commences with the following remarks:—"One of the most important questions which geology is called upon to solve, is to settle the parts in the formation of the solid envelopment of the globe which are to be ascribed respectively to aqueous and igneous action. Although it has been long debated, it has as yet received no definite solution; it has even become complicated, since by a more rigorous examination of different rocks we have discovered evidence of a twofold origin. Was it at the very moment of their formation that these ambiguous rocks received this double character, or was the one consecutive on the other? and, in the latter case, how can we account for such a succession of effects? These are subjects the study of which constitutes what in their more extended and general sense we term metamorphism." He gives a historical sketch of the gradual development of those observations on the structure of rocks by some of his predecessors which have led the way to the views now generally adopted. In giving a list of the English geologists who have advanced this branch of our science, he most strangely omits the name of Lyell—of him who was the first, twenty-seven years ago, to suggest this modification and restriction of the Huttonian theory, and who in the several editions of his 'Manual of Geology,' a work quoted by M. Daubrée, has so fully discussed the whole question of metamorphism, so far as it had advanced, not even omitting the possible agency of water at an intensely high temperature, in producing it, by an internal movement and re-arrangement of the molecules*.

After noticing some remarkable statements in the works of Descartes and Leibnitz, he passes to the more modern names of Buffon, Saussure, Pallas, and Werner, and then dwells at some length on Hutton and his illustrator Playfair, in whose works, he says, we find established and developed, for the first time, certain fundamental principles of modern geology, and especially metamorphism. After pointing out the fundamental hypothesis of Hutton, that the strata had been formed by the detritus of pre-existent rocks and afterwards consolidated by heat, he adds,—"Thus, by an idea entirely new, the illustrious Scotch philosopher showed the successive cooperation of water and the internal heat of the globe in the formation of the same rocks. It is the mark of genius to unite in one common origin phenomena very different in their nature. Hutton first pointed out that subterranean heat had not only consolidated and mineralized the deposits at the bottom of the sea, but had moreover raised up and thrown into inclined positions beds which had originally been horizontal. Another discovery due to Hutton, which has also been of capital importance in geology, is the eruptive origin of granite. He further demonstrated, by numerous examples exhibited in Scotland, that the trap-rocks had been injected into regions where there is no indication of a volcano. Hutton explains the history of the globe with as much simplicity as grandeur. Although, by considering the process of decay and renovation a continuous phenomenon, he has thrown a shade over his noble conception, he has rendered immense services in demonstrating that natural causes which operate under our view are sufficient to explain the history of the globe, and that it is unnecessary to have recourse to other modes of action than those exhibited by nature in our own day; whereas other systems that had been devised assumed, on the contrary, events which had no analogy with what we now witness. Thus Hutton is truly the founder of the fertile principle of the transformation of the sedimentary rocks, by the action of heat. Nevertheless, we shall notice hereafter that there are many deductions to be made from conclusions so absolute. Like most men of genius who have opened up new paths, Hutton exaggerated the extent to which his conceptions could be applied. But it is impossible not to view with admiration the profound penetration, and the strictness of induction of so clear-sighted a man, at a period when exact observations had been so few; he being the first to recognize the simultaneous effect of water and heat in the formation of rocks, in imagining a system which embraces

* Fifth edition, p. 606.

the whole physical system of the globe. He established principles, which, in so far as they are fundamental, are now universally admitted."

I trust that I shall be pardoned in thus giving prominence to a tribute offered, at this distance of time, by so eminent a foreign geologist, to the genius and sagacity of Hutton, of whose ingenuity, acuteness, and even light-hearted playfulness, I had been accustomed in my early life to hear much in my own family, although too young to have any personal intercourse with him; and in whose scientific principles I was trained in my geological studies under the guidance of my venerated friend the able and eloquent Playfair. I am, however, not prepared to agree with M. Daubrée that a shade has been thrown over Hutton's "noble conception" that a continuous process of decay and renovation of the materials of our globe had from the origin of the stratified rocks been the established order of nature; that observations since the time of Hutton have demonstrated any interruption to that continuity in past time, or justify any anticipation of a future change.

In this work, as well as in the more recent one of M. Delesse, metamorphism is not limited to the class of rocks to which the term metamorphic was originally applied: on the contrary, M. Daubrée expressly says, "Des effets de l'action métamorphique se montrent dans les terrains de divers âges" (p. 119), and, at p. 74, that "les dépôts métallifères ne sont que des cas particuliers des phénomènes métamorphiques." These three essays, in place of being called "Études sur le Métamorphisme," might have had, in my opinion, the more appropriate and comprehensive title of "Contributions to the Chemistry of the Mineral Kingdom." And most valuable contributions they assuredly are; for the facts and experiments they narrate enable us to form some just conception of the agencies by which the lower sedimentary deposits became changed into hard and crystalline rocks, and how their included accessory minerals may have been produced; they are also calculated to throw light upon the analogous changes of structure met with in the fossiliferous strata of all ages, but which must have been produced under very different circumstances, and likewise upon the formation of the various products of mineral veins. Even a short summary of the contents of these essays would of itself amount to a treatise; so I must refer you to the works themselves, noticing only some of the conclusions of the authors to which I wish to call your attention.

M. Delesse certainly states that the agencies in general metamorphism must have been heat, water, and pressure; but the main feature in both his essays is the prominent part which he considers water to have played in the production of mineral compounds. He brings forward many facts for which the sole action of heat appears to afford an inadequate explanation; but, on the other hand, he seems to be carried away by his theory to ascribe far too extended an operation to aqueous causes. Thus, he affirms it as his opinion that the trap of the Giant's Causeway was not incandescent and in a state of igneous fusion when it was poured over the lignite it covers; and in referring to the Meissner, near Cassel, so long celebrated as an instance of the igneous origin of basalt, where a mass of it, in some places 500 feet thick, covers beds of lignite from 20 to 98 feet in thickness, he says that the phenomena exhibited are to be ascribed "plutôt à une action aqueuse qu'à une action ignée." Not only in the above, but in other instances, he maintains the aqueous plasticity of trappean rocks. Water may be one of their constituents; but it is in no degree probable that it held the earthy constituents in a softened, plastic, or fluid condition. It will require stronger proofs than M. Delesse has as yet brought forward, to set aside the long-established conviction of the similarity of origin of the Giant's Causeway and Fingal's Cave to that of the columnar lavas of Etna and Auvergne.

Although M. Daubrée does not carry his views of aqueous action so far as M. Delesse does, he nevertheless expresses very decided opinions as to the powerful agency of water in metamorphism, as the following passage will show:—

"It is, therefore, not difficult to see, in the various kinds of phenomena of which I have spoken, the manifestations of one and the same agent, which exists throughout entire countries. That essential agent is water, aided by heat of different degrees, and to which are superadded as secondary causes, emanations which accompany it. Thus we are of opinion that water acts unceasingly in the deep-seated regions, after it has acquired a temperature more or less elevated, under the influence of the heat of the globe."—"It cannot be denied that if water is able to insinuate itself, through fissures in the solid crust of the globe, to a depth equal only to that of the sea, it becomes subject there to a pressure equal to several hundreds of atmospheres, by means of which it will penetrate easily to the inmost pores of the rocks, especially when it is of a temperature which it must possess at such a depth." (pp. 97 & 117.)

On this agency of water the following testimony of Prof. Bunsen of Heidelberg is important:—"The attention of geologists has hitherto been almost solely directed to the action of heat in the production of the metamorphism of rocks. The action of gases and of water at a moderate temperature in producing changes of structure, which may be seen on a small scale in fumaroles, must have had immense influence, as after-effects of older plutonic catastrophes, upon the materials of which the stratified rocks are composed. In this treatise I have endeavoured to bring forward some proofs and circumstances which may perhaps set geologists upon the track of those processes. Everything indicates that, in future, we must rely not so exclusively on observation, but more upon experimental researches to enable us to explain the metamorphism of rocks by hydatothermic and pyrocaustic, or, where both have acted, by hydatocaustic processes. I know not whether the time is yet arrived for the introduction of those terms; but distinctions will be devoid of meaning unless the test of experiment has determined their true value, in every point of view*."

* Bunsen, über den innern Zusammenhang der pseudo-vulkanische Erscheinungen Islands.

Professor Naumann in his 'Lehrbuch der Geognosie,' the most copious and instructive general treatise on geology with which I am acquainted, briefly notices the conjectures of other geologists as to the agencies in normal or general metamorphism, without expressing any decided views of his own, except as to what heat may be supposed to have effected. But he enters at considerable length into the subject of abnormal or local metamorphism. He justly observes that while here the origin of the effect is apparent, the *modus operandi* is far from being equally so in a great proportion of cases. In the generality of instances the heated state of the intrusive rock appears to have been the cause; but he adds, "it is nevertheless evident that many of the appearances when ordinary sandstones and quartzose conglomerates are changed into quartzite by the contact of granite, syenite, and other pyrogenous rocks cannot be explained by the action of heat alone. For it is difficult to conceive that heat, which in its continuous state, at least, could not have been very great, and must at all events be much under the melting-point of silica, could convert a fragmentary sandstone into crystalline quartzite. It is clear that such contact-metamorphism must belong to those instances the production of which without the concomitant action of *water* is inconceivable *."

There is an observation of M. Daubrée, which, so far as I know, is novel and is well deserving of being followed up in researches in metamorphism. He states that cases of the metamorphism of sedimentary rocks occur only in those situations where disturbances of the horizontality of such deposits have taken place: that the oldest strata of Russia, Southern Sweden, and North America have preserved their original horizontality and are not sensibly metamorphosed. That, on the other hand, newer strata which have been much broken up and elevated, such as the jurassic and cretaceous formations of the High Alps, the Apuan and the Tuscan Alps, have been completely modified, few only of the eruptive rocks being met with among them: that clay-slates are but the beginning of more deeply-seated transformations, and occur only in regions more or less disturbed: that hot springs are always connected with accidents in the structure of a country of a similar kind: that it is therefore difficult not to perceive a connexion between the two phenomena, and no less difficult to refuse one's assent when we learn by experiment that the mineralized waters are among the most energetic agents in that metamorphism which we can artificially produce †.

Gneiss is generally held to be a metamorphic rock, meaning thereby that it was originally a sedimentary deposit of the detritus of a preexistent surface-rock, altered by subterranean heat as the chief agent. There are, however, some considerations which make it difficult for me to understand the *modus operandi* of this supposed thermal action; that is, in what manner the heat could be applied, in accordance with known chemical laws. If gneiss be, as it is usually held to be, the lowest known of the sedimentary stratified

* Lehrbuch der Geognosie, i. 793.

† Observations, &c. p. 38.

rocks, it is obvious that it must necessarily have been formed by the detritus of an original *un*stratified surface-rock, which had been exposed to the wearing effects of atmospheric action and of waves acting upon a shore. The detritus, in order to form stratification, must have been spread gradually over the solid bottom of a deep sea. The generally prevalent theory assumes that the altering heat was communicated through the rock on which the sediment rested, that is, the sea-bottom. Now unless we assume that the sea was in a state of ebullition, the bottom rock must have been cold, by being in immediate contact with cold water; for so soon as the sea-water came in contact with a heated mass, immediately there would be produced two continuous currents, of ascending warm and descending cold water, until the whole sea was raised to a high temperature. By the pressure of the superincumbent water, the boiling-point in the lower depths would be greatly raised, and the constant production and upward direction of high-pressure steam would cause such a turmoil in the sea that no tranquil deposition of sediment to form stratification could possibly take place. If the source of heat were local, the colder water from the adjoining parts of the sea would rush to the heated parts. If the bottom rock did not become heated until after the sediment had accumulated to a great thickness, it is obvious, from the very slow conducting power of rocks, that the lower parts, if brought by the heat into such a softened state as to acquire a crystalline structure, must be very different in nature from the upper parts of the deposit,—that, in short, there would be a gradual change in the texture of the rock upwards—a difference which has nowhere been observed. A similar difficulty attends the hypothesis in other cases besides that of gneiss, when metamorphism is considered to have been produced by sedimentary deposits having been acted upon by a highly heated hypogene rock at the bottom of a sea.

As gneiss has never been seen to contain an undoubted fragment of a pre-existent rock, nor any trace of an organism, its being held to be an altered sedimentary deposit would seem to rest, first, on its schistose and bedded structure, and, secondly, upon the extreme improbability of an eruptive rock having spread over vast regions with that structure. As regards schistose and bedded structure, that is of itself no conclusive proof. Gneiss is essentially composed of the same materials as eruptive granite, and there are numberless instances, on a great scale, of a gradual passage from coarse-grained granite into schistose gneiss. Some of these I will quote.

Dr. MacCulloch, in his 'Description of the Western Islands,' when treating of gneiss, which prevails in the Northern Hebrides, observes* that there are two principal varieties, the one of a granitic, the other of a schistose structure; that the gneiss of these islands (Flannan Isles) is in general composed of quartz, felspar, and mica; that it presents as usual many varieties, and among the rest, one which cannot be distinguished from common granite; that this consists of an equal mixture of flesh-coloured felspar, quartz, and but little mica, forming beds among the rest of the rock; that there is not a trace

* Vol. i. pp. 202 & 226.

of laminar tendency in their structure, and therefore, although they may be considered as forming portions of the gneiss beds, they present, in strictness, an example of bedded granite. He then goes on to say that the limits which separate gneiss from granite are evanescent, and that of this perpetual gradation there is scarcely a mile of the survey of those islands which does not offer an example; that the granitic subdivision prevails, and is characterized not only by a large grain and imperfectly foliated structure, but by frequent transitions into granite, from which, when in detached specimens, it cannot be distinguished.

As instances out of our own country of this intimate relation between varieties of gneiss and granite, I may give the following:—Carl von Roemer, as quoted by Naumann*, while describing the northern side of the central granite of Siberia, mentions an extensive tract of *granit-gneiss* in which a laminar and bedded rock repeatedly alternates with one of granular and massive structure without lamination; and in like manner, in Podolia, granite and gneiss form a massive, intermixed, and compact whole, demonstrating a contemporaneity and similarity of origin of both. Beudant states that in Hungary gneiss and granite appear always together, and that they occur not only in alternating beds, but as one and the same mass. Elie de Beaumont† states that a passage between granite and gneiss, gneiss and mica-schist, and even between granite and mica-schist, is so often observed as to prove, in such cases, their common origin; that there are instances in which it is evident that gneiss must have been an eruptive rock, which, after its eruption, had been drawn out so as to assume a schistose or, rather, a fibrous structure, so that it is often difficult to distinguish between the two kinds,—that is, between eruptive and metamorphic gneiss. M. Delesse says, that gneiss forms a transition between stratified and eruptive rocks; that its mineralogical composition, as well as its mode of occurrence, unite it in a manner the most intimate with granite, and that its origin is evidently the same‡. The section of granite and gneiss at Jaegersborg, in Norway, given by Mr. David Forbes§, proves indisputably, I think, that there the two rocks must have had a common origin, and that it is not conceivable that this gneiss can be an altered sedimentary rock.

When stratified gneiss contains, as it often does, a variety of accessory simple minerals, and metamorphism by contact likewise produces them in the traversed rock, we have a complication of chemical action for a right understanding of which we must look to synthetic experiment. Thus we know || that, in limestones especially, a great variety of minerals are often produced by the contact of granite, among which garnet, idocrase, hornblende, wollastonite, epidote, talc, chlorite, and zeolites are the most common. Now to produce these eight minerals, there must be derived from the granite

* Lehrbuch der Geognosie, 1st ed. vol. ii. p. 84. † *Loc. cit.*
‡ Etudes, &c., 4to, p. 203.
§ Quart. Journ. Geol. Soc., vol. xv. p. 173.
|| Daubrée, Etudes et Expériences synthétiques, p. 57.

and the limestone ten different elementary constituents, as the following table of the analyses of them shows :—

	Silica.	Alumina.	Lime.	Magnesia.	Protoxide of Iron.	Peroxide of Iron.	Protoxide of Manganese.	Fluorine.	Soda.	Potash.	Water.
Garnet	*	*	*	*	*	*	*				
Idocrase............	*	*	*	*	*	...	*	...	...	...	*
Hornblende	*	...	*	*	*	...	*	*	...	...	*
Wollastonite	*	...	*	*	...	*	...	...	...	...	*
Epidote	*	*	*	*	*	...	*				
Talc	*	*	...	*	*	...	...	...	...	...	*
Chlorite	*	*	...	*	*	...	...	...	...	...	*
Zeolites	*	...	*	...	...	*	...	...	*	...	*

It belongs to the chemist to show under what conditions these elementary substances could, in the same mass, combine into two or more of those definite forms. They are phenomena of metamorphic action, of which, until explained, we cannot form any just conception of that great operation of nature.

But there are accompaniments of many rocks that have received the name of gneiss which would seem to favour the hypothesis of a hypogene rather than a sedimentary origin, viz. intercalated masses of granular and crystalline limestone, and metallic ores in masses and disseminated through the substance of the rock.

MacCulloch describes* the gneiss of the island of Tiree as containing masses of crystalline limestone, without stratification or continuity ; and it also occurs with a great variety of accessory crystallized simple minerals in the gneiss of Norway†, Sweden, Saxony, Bavaria, Austria, and in different States of North America. Whence the origin of this limestone thus contemporaneous with gneiss ? It cannot have been derived from the detritus of any surface-stratum ; for no other than an eruptive rock could as yet have formed a part of the dry land. If we could suppose it to be formed by the exuviæ of marine organisms, it would be carrying the prevalence of animal life far beyond any period in which its existence has ever been contemplated, except that Sir William Logan has suggested that nodules of phosphate of lime found in sedimentary rocks of Lower Cambrian or even greater age may have a possible connexion with life existing at that very remote period of the earth's history ; or if derived from springs holding carbonate of lime in solution, that of itself would be a proof of a hypogene origin. Many instances have been met with of granular limestone occurring under circumstances that can only be explained by supposing them to have had a subterranean origin. Nearly forty years ago, Von Oeynhausen‡ (elected a Foreign

* Description of the Western Islands, vol. i. p. 48.

† At Jaegersborg. See section by Mr. D. Forbes above referred to.

‡ Nöggerath's Rheinland-Westphalen, vol. i. p. 163, 1822.

Member of this Society in 1827) described a dyke of great extent, composed of saccharoid limestone, traversing a granitic ridge in the Bergstrasse, between the villages of Auerbach and Schönberg; it was specially noticed by Von Leonhard* in 1833, who says of it, that a close examination left the impression that it was erupted in a state of igneous fluidity from the depths of the earth subsequent to the formation of the gneiss; for the granitic rock there appears both with a gneissic structure and as syenite. And in 1852 Voltz† thus describes it:—"The whole appearance of the limestone is that of a dyke; and there can be no doubt that we have one of colossal size,—the limestone being crystalline, and showing all varieties of structure from fine-grained to calcareous spar." Similar occurrences have been described by Emmons in the State of New York, by Clarke in Australia, and by Dumas in the Cevennes‡; and instances of veins of large dimensions of calcareous spar, with numerous ramifications, having as much the appearance of injection from below as veins of granite or trap, must be familiar to every geologist.

The gneiss of Norway and Sweden, in many parts, contains, disseminated through the substance of the rock and in masses of vast magnitude, ores of magnetic iron, of silver, copper, cobalt, zinc, and arsenic; in Saxony it has been found containing tin, arsenic, iron, and copper; in France, in the department of the Aveyron, it abounds in magnetic iron; and the same combination is met with in different parts of the United States. These metallic minerals are surely much more probably of subterranean than of sedimentary origin.

There is no manner of doubt that there are vast tracts of gneiss with such distinct stratification, often greatly contorted, to which no other than a sedimentary origin can with any degree of probability be ascribed, however difficult it may be, in the present state of our knowledge, to comprehend the nature of the chemical action by which the original component materials have been altered into new combinations. On the other hand, the assertion that *all* gneiss has had the same origin appears to me erroneous, for the reasons I have assigned; and it is distinctly contrary to the opinion of some of the most distinguished geologists of France and Germany.

A rock is now very commonly said to be metamorphic in such a variety of cases, without any qualification of the term, whether in relation to the nature of the materials acted upon, or to the totally different texture of the rocks beneath, which have for hundreds or thousands of feet undergone no similar alteration, that it is impossible to arrive at any other conclusion than that there must have been different agencies at work—that the subterranean thermal action considered to have produced gneiss from detrital matter could not have produced the crystalline rock intercalated in a tertiary deposit. Palæontological determinations are made under the guidance and control of the acknowledged laws of anatomy and physiology;

* Neues Jahrbuch für Mineralogie, &c., 1833, p. 312.

† Uebersicht der geologischen Verhältnissen des Grossherzogthum Hessen, p. 107.

‡ Naumann, Lehrbuch der Geognosie, 2nd edition, vol. ii. p. 88.

so in cases of metamorphism chemistry must assert her authority. If the term "metamorphic" is to be used in any other sense than merely as a synonym of the word "altered," it is clear that a wide field of chemical research has to be cultivated before it can be justly applied in a theoretical sense.

Endeavours to unravel the mystery of general metamorphism may, at first sight, appear to be a hopeless task; and doubtless it is, so far as regards the effects of a vast period of time. But by experiments with the means within our power—that is, by heat, water, and pressure, skilfully applied, under a variety of forms—we may reasonably expect to acquire some just conception of the processes by which mechanical detritus could have been converted into a homogeneous crystalline mass. Even as regards time, recent researches have shown the contrast of the effects of the same agents when brought shortly to a close and when they are prolonged for several months. We must have multiplied synthetic experiments of the kind of those instituted by Sir James Hall and Gregory Watt, and since conducted with so much ingenuity and perseverance by Bischof, Daubrée, Delesse, Sorby, and others; we must have it proved that, by the combined action of heat, water, and pressure, something resembling gneiss, mica-slate, clay-slate, and quartzite, with their accessory simple minerals, may be formed out of sedimentary materials. But such experiments must, unfortunately, be of a kind and on a scale that very few individuals can be expected to undertake; and they are therefore fit subjects for liberal grants from public bodies entrusted with funds for the promotion of science.

I will now pass to a very different subject—to one which may be said to have been for nearly two years the great geological question of the day, and which has excited no small amount of general interest,—the discovery of

Evidence of the early Existence of the Human Race.

Numerous newly discovered facts, and a more attentive and unprejudiced estimate of many of a similar kind, long since recorded, seem to prove indisputably that Man must have been an inhabitant of this earth at a far earlier period than we had been accustomed to believe him to have existed. Ever since the discovery by Dr. Falconer in 1858 of implements of human workmanship associated with the bones of extinct quadrupeds in the cave at Brixham in Devonshire, and the subsequent communication of Mr. Prestwich to the Royal Society in May 1859, of his examination of the ground where M. Boucher de Perthes had discovered, in a bed of gravel, flint hatchets associated with the bones of extinct quadrupeds, at St. Acheul near Amiens, and at Abbeville, this question has been a topic of intense geological interest. Soon after the visit of Mr. Prestwich, to whose paper in the Philosophical Transactions I must refer you for ample details, M. Gaudry, a French geologist, went to St. Acheul, and in two communications to the Academy of Sciences of France, on the 26th of September and 3rd of October, 1859, he gives the following account of his researches:—"The great point was not to leave the workmen for a single instant, and to satisfy oneself by actual inspection whether the hatchets were found *in situ*. I caused a deep excavation to be made, without quitting the workmen for a moment: I found nine hatchets most distinctly *in situ*, in the diluvium, associated with teeth of *Equus fossilis*, and a species of *Bos* different from any now living and similar to that of the diluvium and of caverns. The exact determination of the position of the hatchets proves, beyond all doubt, that Man had been contemporary with several of the larger animals that no longer exist, whose bones are now fossil. One may easily be satisfied that the gravel beds are in their normal state, and that they have not been *remaniés* by man. At St. Roch, near St. Acheul, the diluvium has been found to contain remains of the *Rhinoceros tichorhinus*, *Elephas primigenius*, and *Hippopotamus*; and M. Buteux has ascertained that the beds of diluvium of St. Roch are continuous with those of St. Acheul*."

On the 7th of last May, M. Beaudoin announced to the Geological Society of France a discovery he had made of worked flints in undisturbed drift in the neighbourhood of Chatillon-sur-Seine; and on the 20th of the same month M. de Verneuil communicated a similar discovery at Precy, in the department of the Oise. Thus we have evidence of the same event in the valleys of the Somme, the Seine, and the Oise. More recently, M. E. Collomb, in a letter published in the 'Bulletin de la Société Vaudoise des Sciences Naturelles' for October 1860, gives an account of a visit he paid to St. Acheul in company with M. Lartet; and he fully confirms the accuracy of the observations of Mr. Prestwich and M. Gaudry, as to the age and undisturbed condition of the gravel in which the worked flints are found. He observes that almost the whole of the north of France, and especially the plains, is in a condition the most favourable, the most normal, for the study of the quaternary deposits (*terrains quartaires*), because, during that long period, no extraordinary events have occurred in that region; there have been no great cataclysms, no sudden elevations or dislocations; no glaciers which could have broken up and rearranged (*remanié*) the soil, and changed the regular order of the superposition of the beds.

Additional evidence in support of the same views has been recently supplied by the publication of a memoir communicated to the Society of Antiquaries by John Evans, Esq., a Fellow of this Society, who accompanied Mr. Prestwich in his examinations at Abbeville and St. Acheul. He states that he was himself witness to the extraction of a worked flint from the gravel bed at St. Acheul, at a depth of 11 feet from the surface, and about $4\frac{1}{2}$ feet from the bottom of the pit; —that, on another occasion, Mr. Flower, one of the party of geologists, uncovered and exhumed with his own hands a perfectly worked instrument at a depth of 20 feet from the surface;—that the implements occur most certainly in undisturbed gravel, for it is so hard and compact as to require the use of a pickaxe, and therefore precludes all idea of its being a reconstructed mass;—that there is every improbability of the bones of extinct species of quadrupeds

* 'Comptes Rendus' of the above-mentioned dates.

associated with the implements having been washed into the gravel from an older deposit; for not only are they little if at all worn, but in the lower beds at Menchecourt, near Abbeville, the skeleton of a Rhinoceros was discovered nearly entire; and thus we have strong, almost conclusive, evidence of the coexistence of Man with these extinct Mammalia;—that it appears to be established beyond a doubt that, in a period of antiquity remote beyond any of which we have hitherto found traces, this portion of the globe was peopled by Man;—that, at Amiens, land which is now 160 feet above the sea, and 90 feet above the Somme, has, since the existence of Man, been submerged under fresh water, and an aqueous deposit from 20 feet to 30 feet in thickness, a portion of which at all events must have subsided from tranquil water, has been formed upon it; and that this too has taken place in a country the level of which is now stationary, and the face of which has been little altered since the days when the Gauls and the Romans constructed their sepulchres in the soil overlying the drift which contains these remains of a far earlier race of men.

At a meeting of the Geological Society of France last April, at which I was present, M. de Vibraye read an account of explorations he had made in a cavern of jurassic rock near Arcy, in the Département de l'Aube, between Troyes and Chalons-sur-Marne, which paper has since been printed in the 'Bulletin' of that Society. This cavern contains three distinct beds of drift, the two uppermost bearing evidence of *remaniement*; but the lowest he is satisfied must be an undisturbed mass of materials washed into the cavern by the same force which spread the pleistocene drift, characterized by the remains of *Rhinoceros tichorhinus, Ursus spelæus*, and *Hyæna spelæa*, over the north-west of France. On making excavations in this lowest bed, he met with a vast accumulation of the bones of the above animals; and among them, one of the labourers, while M. Vibraye was in the cavern, found *a human jaw*. M. Vibraye thus describes this remarkable event:—" Judge, gentlemen, of my surprise, when I saw a human jaw. I felt disposed to doubt the reality, and to believe that it was the jaw of an ape; but no, the doubt could not remain for an instant; for the jaw, all the alveoli of which are perfectly seen, still contained two well-characterized teeth, viz. the first right lower premolar and the first large molar of the same side. I hastened to satisfy myself not only as to the situation, but as to the actual place this important remain had occupied, and I can affirm that the homogeneous bed, the lowest bed in the cavern, was perfectly intact, and had in no respect changed its nature. I found this jaw while devoid of all preconceived ideas, and was even obliged to do violence to my individual convictions to admit the evidence. To add to the value of this discovery, I ought to add that, while arranging the numerous remains collected in this cavern during the last two years, I found the tooth of another man, a first premolar of the lower jaw belonging to an individual of less size than he to whom the jaw belonged. This would tend to prove that the first discovery is not an isolated fact, and that it is more than probable that further confirmation would be found by continued researches." The paper gave rise to an animated discussion; and M. Lartet, one of the speakers, stated that he had visited the cavern, and had examined the collections of M. de Vibraye, whose identifications he confirmed, and that he was of opinion that the drift in which they were found is of the same age as that of St. Acheul.

The confirmation of the correctness of the conclusions to which M. Boucher de Perthes had arrived, which he had published ten years before, but which, by a strange unreasoning incredulity not very creditable to the scientific men of all countries, had been suffered to be neglected, is of an importance that cannot be overrated, inasmuch as it is calculated to remove a prejudice that has long prevailed among geologists the least timid in forming conclusions, and as it bids fair to eradicate one of a similar nature deeply rooted in the minds of even the educated part of the general public.

It has been well remarked by the Rev. Mr. Kenrick, in his interesting essay on Primæval History, that, "As we can assign no absolute date to the introduction of man into the world, nor even decide with confidence whether this took place by simultaneous or successive acts of creative power, so it is impossible to define the time which he occupied in advancing from his primæval condition to that in which he appears at the commencement of history*." Now, although we are unable to give any numerical expression to the time of the occurrence of events that have preceded all historical records or traditions, we may arrive at a very firm conviction that they must have been extremely remote, by a consideration of the very slow process by which changes take place on the surface of the land, and in the forms of the coasts which are evidently altered by the wearing forces of the atmosphere and the sea, without any cataclysmal action. The long duration of the vegetable soil and its covering of turf and forest, and the resistance to the wearing effects of the weather by many human works in stone have been well pointed out by M. Elie de Beaumont†. He observes that plants fixing by their roots the superficial soil add greatly to its stability,—that the natural state of the globe has been to be covered with vegetation,—that its surface has been covered by turf or by forests,—that when we see turf on a mountain-slope we may affirm that it has been almost coeval with the slope, and that it has preserved the soil it covers for thousands of years,—that the soil surrounding Cyclopean and Druidical monuments, which have existed for more than 2000 years, has undergone no change either of increase or decrease,—that the existence of a tree shows that the surface of the vegetable soil has undergone no sensible change during the growth of the tree, and that there are trees which have existed for many centuries." Professor Phillips in his recent publication‡, in reference to the slow process by which peat accumulates, has the following passages:—"Man and the works of man have been pre-

* An Essay on Primæval History. By John Kenrick, M.A. London: Fellowes, 1846.

† Leçons de Géologie Pratique, Leçon 5.

‡ Life on the Earth, its origin and succession, pp. 48, 49. 1860.

served in natural repositories of higher antiquity than all the mausoleums, and tumuli, and ὑπόγαια,—in caverns, in peat-bogs, lacustrine and river sediments, which derived their characteristic features from the operation of physical conditions long since passed away. Thus, deep in the sediments of many of our British valleys, left by the rivers in some earlier period, we find the canoe of the primitive inhabitant, hollowed by fire and rude stone chisels from the trunk of the native oak." "To heap twenty or more feet of sediment over the buried canoes by the ordinary operation of a river like the Yorkshire Aire would require thousands of years: if it were not accumulated under the ordinary circumstances now in operation, but under different geographical conditions, this would perhaps require the hypothesis of still longer time. In the alluvial sediments of this same valley lie nearly complete skeletons of the extinct *Hippopotamus major*; in another place jaws and horns of the deer, and hazel wood and nuts, some of them petrified. Perhaps Man was contemporary with this extinct Hippopotamus, which has also been found in the peat-deposits of Lancashire. The gravel of Amiens and Abbeville appears to furnish evidence of a higher antiquity for the flint implements found there."

The discovery in Egypt of works of art executed more than 3000 years before our era, which could only have been produced by a people arrived at an advanced stage in the slow process of civilization (a conviction that has been strengthened by the recent discovery of works of human art at great depths in the alluvial soil of the Nile valley, which accumulates at the average rate of a few inches in a century*) has been gradually producing an impression in the minds of earnest thinkers that the first appearance of man on the earth must be carried far beyond the time hitherto usually assigned to it. When we come to reflect upon the geological changes that have occurred in the configuration and structure of the country in the north of France where the flint implements are found, proved by the nature of the deposit in which they are met with and its elevation above the sea-level, and take into account the length of time which, according to all sound reasoning on geological phenomena, we must assign for the accomplishment of those changes, the largest sum of years which has been assigned for the existence of man in Egypt can scarcely amount to more than a fraction of the time that has elapsed since the men lived who chipped those flint implements.

The ground in which those worked flints were found at Amiens and Abbeville is a part of a great post-pliocene deposit which is spread over a great extent of the north of France, the geological age of which is determined by the fragmentary materials, and by the nature of the fossil remains of extinct species of quadrupeds. It is marked in the geological map of France as composed of the group designated the "*Alluviens anciennes de la Bresse, Sables des Landes, Sables marins supérieurs de Montpellier*," resting upon another group designated "*Fahluns, Meulières, Grès de Fontainebleau*," &c. That

* Memoirs on the Alluvial Land of Egypt, Phil. Trans. 1855, p. 105, and 1858, p. 53, by the Author.

part of it at St. Acheul consists of a bed of flint-gravel from 6 feet to 12 feet thick, resting on chalk. It was in this gravel that the worked flints were found, and in the lowest part near the chalk. It has been alleged that the gravel in this place is a case of what the French call a *remaniement*, that is, an accumulation of the diluvial gravel that had been disturbed by a local flood, or by man, which involved in it the works of art belonging to a comparatively recent time. But no evidence of this has been brought forward, and it has been distinctly denied by M. Gaudry and Mr. Evans in the papers quoted above. Other experienced geologists who have examined the localities, both at Amiens and Abbeville, entertain no doubt that it is an undisturbed deposit. I visited St. Acheul last April, and am surprised that any one could see the least sign of a *remaniement*.

Another and a very decisive proof of the coexistence of Man with extinct species of quadrupeds has been brought forward by M. Lartet, a Foreign Member of our Society, in a paper read before us last May, as well as in a communication in the same month to the Geological Society of France. He there points out numerous instances of intentional incisions by a sharp but rude instrument in such bones. These incisions exist when the bones are disinterred; and if the bones unquestionably belong to extinct species, and if the deposit in which they are found is certainly undisturbed ground, the evidence is complete. All these conditions are fulfilled in the cases brought forward by M. Lartet. He exhibited the specimens to myself in the Museum of the Jardin des Plantes at Paris last spring.

To assign any approximate date for the age when the people who formed these flint implements existed is impossible, in the present state of our knowledge. But M. Lartet, who is not more distinguished by his palæontological knowledge than by habitual caution, has not hesitated to express his belief on this subject in the following terms in the paper in our Quarterly Journal I have already referred to :—" M. d'Archiac has been led, by a series of well-weighed inductions from stratigraphical considerations, to consider the epoch of the separation of the British Islands from France as occurring after the deposition of the diluvial rolled pebbles, and before that of the ancient alluvium, the Loess of the north of France, of Belgium, the valley of the Rhine, &c. The inference to be drawn from that hypothesis is self-evident: it is this, that the primitive people to whom we attribute the hatchets and other worked flints of Amiens and Abbeville might have communicated with the existing country of England by dry land, inasmuch as the separation did not take place until after the deposit of the rolled diluvial pebbles, from among which the hatchets and worked flints have been collected."

Every geologist must be of the opinion of M. d'Archiac, that the lands of England and France were once united—and that at no very distant period in geological time, from community of structure and from the occurrence of the remains of extinct species of quadrupeds in England which could only have come to us over continuous land. Mr. Evans, in the memoir above cited, states that the gravel at St. Acheul closely resembles that on some parts of the Sussex coast, and that the beds at the Moulin Quignon, near Abbeville, are nearly analogous to those near the East Croydon station and in many parts of the valley of the Thames. The late Professor Edward Forbes, in his remarkable paper on the Fauna and Flora of the British Isles (pp. 343 & 346), observes that "no geologist doubts the ancient union of the two sides of the Channel;" and he considers that union to have existed as late as the post-pliocene age; for he says that "during the post-pliocene epoch, *over the elevated bed of the glacial sea,* the great mass of the flora and fauna of the British Isles *migrated from the Germanic regions of the Continent.*" We know that only a very moderate change in the configuration of the two coasts has taken place during the more than 1900 years since Julius Cæsar crossed the Channel. Even if the Channel was first formed by a sudden break and sinking of the land, we cannot conceive so vast a gulf to have been worked out into its present forms on both sides by the wearing action of the sea, except during a period of vast duration.

The discoveries by Dr. Falconer and Baron Anca of siliceous stones in forms that are evidently the work of man, mixed with the remains of extinct species of quadrupeds, in the island of Sicily, are associated with phenomena which indicate that a rupture in the continuity of a continental land took place subsequently to the existence of man, on a still greater scale than the channel which separates England from France; for they can only be explained by assuming that the land now forming the island of Sicily was at that period a part of the continent of Africa. Not only have bones and teeth of the existing African Elephant and Hyæna been found in great abundance, but such enormous quantities of the bones and teeth of the Hippopotamus, that they were carried, for a short time, in ship-loads to France, in the expectation that they might be used as agricultural manure, until it was discovered that they were so far fossilized as to have lost their gelatine. Now it is clear that the African Elephant and Hyæna could only have come by land to those parts of Sicily where their remains are now found. The distance between the nearest part of Sicily and the coast of Africa, that is, between Marsala and Cape Bon, is not more than about eighty miles; and Admiral Smyth, in his memoir on the Mediterranean, states (p. 499) that there is a subaqueous plateau, which he named Adventure Bank, uniting Sicily to Africa by a succession of ridges about a spot where he found from 40 to 50 fathoms of water.

In a communication lately made to our Society by Captain Spratt, relative to a cave near Kredi, on the south side of the island of Malta, in which there was a stalagmitic bone-breccia, he informs us that he discovered large quantities of the bones of the Hippopotamus. Malta is 58 miles from the nearest point of Sicily, and 179 from Cape Demos, the nearest point of the mainland of Africa. Between Malta and Cape Passaro in Sicily, the charts give soundings of 28, 62, 93, and 30 fathoms.

As the shaped stones are, in the opinion of Dr. Falconer and Baron Anca, so associated with the bones of the quadrupeds as to lead to the inference that the hands which fashioned them must have been contemporaneous with the animals, that part of the human race must have been in existence at the commencement of the time required to remove the greater part of the land now occupied by sea between Sicily and Africa. Nor is this all; for if Dr. Falconer and Baron Anca be right in their belief of Man having been a contemporary with the Hippopotamus, the most probable explanation seems to me to be this,—that since the commencement of man's existence there must have been a continent, now submerged, with the exception of those parts of it that now form Sicily, Malta, and Gozo, through which a great river flowed, in whose waters vast herds of those monstrous animals swam, and on whose marshy banks they bred for successive generations.

Modern discoveries in ethnology and philology afford cumulating proofs of the very remote antiquity of the human race. The Rev. Dr. Williams, in his review of Bunsen's 'Biblical Researches,' observes:—"There is no point in which archæologists of all shades were so nearly unanimous as in the belief that our Biblical chronology was too narrow in its limits; and the enlargement of our views, deduced from Egyptian records, is extended by our author's reasonings on the development of commerce and government, and still more of languages, and physical features of race. How many years are needed to develope modern French out of Latin, and Latin itself out of its original crude forms! How unlike is English to Welsh, and Greek to Sanskrit, yet all indubitably of one family of languages! What years were required to create the existing divergence of members of this family! How many more for other families, separated by a wide gulf from this, yet retaining traces of a primeval aboriginal affinity, to have developed themselves, either in priority or collaterally! The same consonantal roots, appearing either as verbs inflected with great variety of grammatical form, or as nouns with case-endings in some languages and with none in others, plead as convincingly as the succession of strata in geology for enormous lapses of time*."

There undoubtedly exists a widespread belief that the first existence of man belongs to a period not very remote from history or tradition. Every discovery which threw a doubt on the correctness of that belief was, until very recently, regarded, even by well-instructed geologists, as an imperfect observation, in which concomitant circumstances had been overlooked, which would have shown that the inference of a great antiquity was erroneous; nor have those who were led to make such inferences been always exempt from the charge of irreverently maintaining opinions at variance with Sacred Writ. To what cause can we ascribe this incredulity? How does it arise that, while the statements of geologists that other organic bodies existed millions of years ago are tacitly accepted, their conclusions as to man having existed many thousands of years ago should be received with hesitation by some geologists, and be altogether repudiated by no inconsiderable number among other educated classes of society? It is true that negative proof is brought forward that human *bones* have never been found associated with those of extinct animals; but granting this to be correct, which recent discoveries show that it is not (and the rarity

* Essays and Reviews, p. 54. London, 1860.

of their occurrence is capable of being accounted for on many reasonable grounds), still against such merely negative evidence we have undeniable proofs, in numerous places, of the existence of such an association with man's *works*, and even many instances of his having applied the bones of such animals to his wants. My own conviction is, that this wide-spread belief of the recent existence of man is to be ascribed, so far at least as this country is concerned, to the impression made by the lesson taught in early youth, the soundness of which is not questioned in after-life, by that marginal note in our Bibles over against the first verse of the first chapter of the Book of Genesis, that "*In the beginning* God created the heaven and the earth" [*four thousand and four years* before *the birth of Christ*]. It is more than probable that of the many millions of persons who read the English Bible, a very large proportion look with the same reverence upon that marginal note as they do upon the verse with which it is connected.

It will be useful to look into the history of this date of 4004 years, given, with so much precision, for the creation, not of this our earth only, but of the universe, and to inquire into the authority by which an addition of so much import is made to the sacred text.

The author of the chronology given in the margin of our Bibles was Usher, Archbishop of Armagh. I make no allusion to any part of the learned prelate's system, except the date he assigns for the creation of the world: that date comes properly within the province of the geologist; for, as the almost religious belief in its accuracy is an obstacle to the acceptance of the conclusions to which he is led by a careful study of the facts which the structure of the earth exhibits, he is fairly entitled to deal with it.

In the eighth volume of the Archbishop's Works*, there is a treatise with the following title:—'ANNALES VETERIS TESTAMENTI, *a prima mundi origine deducti*,' and in p. 13 of that treatise we find the following sentence:—"*In principio creavit Deus cœlum et terram, quod temporis principium, juxta nostram chronologiam, incidit in noctis illius initium, quæ vigesimum tertium diem Octobris præcessit, in anno periodi Julianæ* 710." Then follows:—"*Primo igitur sæculi die, Octobris vigesima tertia, feria prima, cum supremo cœlo creavit Deus angelos: deinde summo operis fastigio primum perfecto, ad ima mundanæ hujus fabricæ fundamenta progressus mirandus artifex, infimum hunc globum ex abysso et terra conflatum constituit.*"

In the eleventh volume of the same edition of the prelate's works there is a treatise with the title—'CHRONOLOGIA SACRA,' in the second chapter of which the Archbishop thus settles the number of years, before the birth of Christ, for the creation of the world:—"*Ita a vespera primum mundi diem aperiente, usque ad mediam noctem initium præbentem*, 25. *quidem diei Decembris, quo Christum natum supponimus, annos Julianos* 3999. *menses τριακονθημερους* 2. *dies* 4. *et horas* 6. *Kalendis vero Januariis anni periodi Julianæ* 4714. (*a quibus vulgaris æræ christianæ exordium deducimus*) *annos* 4003. *menses* 2. *dies* 11. *et horas* 6. *decurrisse colligimus.*" This, therefore, is the authority upon which the confident belief is founded,

* Edition printed at Dublin in 16 vols. 8vo.

that man could not possibly have existed upon the earth for a longer period than considerably less than 4000 years B.C.

But this determination of the Archbishop is only one of many dates which chronologists, in their vain calculations, have presumed to assign to this the most stupendous of all events, to attempt to form a faint idea of which, in anything relating to it, will ever be gross presumption and folly. In the well-known work, 'L'Art de vérifier les Dates,' the following passage occurs:—"Les chronologistes sont loin d'être d'accord sur le nombre des années du monde. Desvignoles (Chronologie de l'Histoire Sainte, préface) assure qu'il a recueillé plus de 200 calculs différents, dont le plus court ne compte que 3483 ans depuis la création jusqu'à l'ère vulgaire, et le plus long en suppose 6984." There then follows a "Table des années écoulées depuis Adam jusqu'à la naissance de Jésus Christ, selon le calcul des principaux chronologistes," numbering 108, beginning with

"Alphonse X, roi de Castille, mort le 24 Avril 1284, dans les Tables de Jean Müller, appelé aussi Regiomontanus 6984,"

and ending with

"Louis Lippoman, savant Vénitien, mort en 1554 . . . . . 3616."

The Rev. Dr. Hales, in his 'New Analysis of Chronology,' gives a similar list of "Epochs of the Creation," and adds:—"Here are upwards of 120 different opinions, and the list might be swelled to 300. This specimen, however, is abundantly sufficient to show the disgraceful discordance of chronologers even in this prime era."

I have endeavoured, by inquiries at Oxford, Cambridge, Edinburgh, and at the Queen's printers in London, to ascertain by what specific authority, Royal or ecclesiastical, the date of 4004 was added to the first verse in Genesis in the authorized version, and I have not been able to discover that any record exists of such an authority. In Lewis's 'Complete History of the Translations of the Holy Bible into English*,' it is stated, in p. 349, that, to an edition in folio of the Bible, published in 1701, under the direction of Archbishop Tenison, Dr. Lloyd, Bishop of Worcester, added chronological dates at the head of the several columns, and on the margin of the title of Genesis the following:—"Year before the common year of Christ, 4004." This edition is to be seen in the British Museum: it was "printed by Charles Bill and the executrix of Thomas Newcomb, deceased, printers to the King's Most Excellent Majesty."

The copy of the Bible in the Bodleian Library, Oxford, in which that date first appears over against the first verse of Genesis, bears the date of 1727; but there is no doubt that for more than a century and a half that unauthorized marginal note has been added, up to the present time†.

* By John Lewis, A.M., 1738. New edition, London, 1818.

† In the Royal Library at Berlin, I last summer found a folio Bible, printed at Liège in 1702, being a French translation with the Latin Vulgate side by side, and over against the first verse of the first chapter of Genesis there is printed in the margin 4004 years for the creation of the world.

Editions of the Bible with marginal notes, printed at Oxford and Cambridge in the year 1858, and an edition by the Queen's Printer in London, with the date of 1860, have the same date for the same event.

I have thus laid before you the origin of this settled point in Sacred History as taught at this day in our schools*, and, from its juxtaposition to the text of the Bible, held in veneration by millions, there is every reason to believe, as an undoubted truth. The study of geology has become so general that those who are instructed in its mere elements cannot fail to see the discrepancy between this date and the truths which geology reveals. The youth is told in the morning at school, probably by his own minister of religion, as I myself have witnessed, that not more than about 6000 years have elapsed since the creation of the world. In the evening he may attend a lecture on geology, very possibly by one of the ninety-three clergymen who are Fellows of this Society, and hear that, in a work just issued from the press (a Lecture by a Professor in the University of Oxford, delivered before the Vice-Chancellor of the University of Cambridge), it is stated that "the probable length of time required for the production of the strata of coal, sandstone, shale, and ironstone in South Wales is half a million of years†." It is thus easy to see what a confusion must be created in the youth's mind, and that he will involuntarily ask himself, "Which of the two statements am I to believe?" There can be very little doubt what his decision would be; for he found the lecturer resting his statement on unmistakeable records preserved in the great book of Nature, the genuine incorruptible register of God's works; whereas his school instructor had adduced no evidence from the sacred text for his averment. To remove any inaccuracy in notes accompanying the authorized version of our Bible is surely an imperative duty. The retention of the marginal note in question is by no means a matter of indifference: it is untrue, and therefore it is mischievous. If in future editions this erroneous date be removed, the omission of any other will best express that entire ignorance of "The Beginning" which no human power will ever be able to dispel.

I cannot conclude this subject better than by quoting the eloquent words of one of the most able and accomplished of our Associates, the Rev. Adam Sedgwick, who, in the Appendix to his Discourse on the Studies of the University of Cambridge, thus expresses himself‡:—

"Between the first creation of the earth and that day in which it pleased God to place man upon it, who shall dare to define the interval? *On this question Scripture is silent*; but that silence destroys not the meaning of those physical monuments of his power that God has put before our eyes, giving us, at the same time, faculties whereby we may interpret them and comprehend their meaning. In the present condition of our knowledge, a statement

* The event is so recorded in three school histories of the Old Testament now selling at the Book Depository of the National Society for Education of the Established Church. In a school-book with the title of 'Scripture Lessons,' published by direction of the Commissioners of National Education in Ireland, "THE CREATION, B.C. 4004," stands at the head of the First Lesson; and in the preface it is stated, "These Lessons, as the name imports, are drawn from the Sacred Volume."

† Professor Phillips, 'Life on the Earth,' p. 134.

‡ Fifth edition, 1850, p. 110.

like this is surely enough to satisfy the reasonable scruples of a religious man. But let us, for a moment, suppose that there are some religious difficulties in the conclusions of geology. How then are we to solve them? Not by making a world after a pattern of our own, not by shifting and shuffling the solid strata of the earth, and then dealing them out in such a way as to play the game of an ignorant hypothesis; not by shutting our eyes to facts, or denying the evidence of our senses, but by patient investigation, carried on in the sincere love of truth, and by learning to reject every consequence not warranted by direct physical evidence. Pursued in this spirit, geology can neither lead to any false conclusions, nor offend against any religious truth."

Appendix to Mr. Horner's *Anniversary Address.*

In stating the evidence for the early existence of the Human Race, I give a passage from an essay by Dr. Williams, to show that modern discoveries in ethnology and philology afford cumulating proofs of the very remote antiquity of man. When that paragraph was printed I had not seen an unpublished memoir, entitled 'On the Antiquity of Man, from the evidence of Language,' by John Crawfurd, Esq., F.R.S., President of the Ethnological Society, and author of 'The Grammar and Dictionary of the Malay Language,' published in 1852. From that memoir I quote, with the permission of the author, the following passages:—

"The periods usually assigned for Man's first appearance on earth necessarily date only from the time when he had already attained such an amount of civilization as to enable him to frame some kind of record of his own career, and take no account of the many ages which must have transpired before he could have attained that power. Among the many facts which attest the high antiquity of Man, the formation of language may be adduced, and in the course of this short paper, I shall endeavour to bring forward a few of the most striking facts which it yields.

"Language is not innate, but adventitious—a mere acquirement, having its origin in the superiority of the human understanding, like any other acquisition derived from the same source. The evidence that such is the case is abundant. Infants are without language, and we see them slowly and gradually attaining it, in proportion as the brain acquires maturity. Children acquire with equal facility any language whatsoever; they can forget the first acquired language, and learn another.

"Among the unquestionable proofs that language is not innate, is the prodigious number of languages which exists,—some with a very narrow range of articulate sounds, others with a very wide one; some with words confined to single syllables, and others having many; some being of very simple, and others of a very complex structure. Such a state of things necessarily implies that each tongue was a separate and distinct creation, or that each horde framed its own independent tongue.

"If additional confirmation of the fact that language is an adventitious acquirement were wanting, it will be found in this, that a whole nation may lose its original tongue, and in its stead adopt any foreign one. The language which was the vernacular one of the Jews 3000 years ago has ceased to be so for above 2000, and the descendants of those who spoke it are now speaking an infinity of foreign tongues,—sometimes European and sometimes Asiatic. Languages derived from a single tongue of Italy have superseded the many native languages which were once spoken in Spain, in France, and in Italy itself. A language of German origin has nearly displaced, not only all the native languages of Britain and Ireland, but the numerous ones of a large portion of America. Some eight millions of negroes are planted in the New World, whose forefathers spoke many African tongues. These African tongues have nearly disappeared, having been supplanted by idioms derived from the German and Latin languages.

"It necessarily follows from what has now been stated, that Man, when he first appeared on earth, was destitute of language. He had to frame one: each separate tribe framed its own, and hence the multitude of tongues. However difficult may appear to us the task of framing a language, there can be no doubt that in every case the framers were arrant savages, which is proved by the fact, that the rudest tribes ever discovered had already completed the task of forming a perfect language. The languages spoken by the grovelling savages of Australia are in this state, and even more artificial and complex in their structure than those of many people far more advanced.

"The first rudiments of language must have consisted of a few articulate sounds in the attempts made by the speechless but social savages to make their wants and wishes known to each other; and from these first efforts to the time in which language had attained the completeness which we find it to have reached among the rudest tribes ever known to us, countless ages we must presume to have elapsed.

"In every department of language we find evidence of the great antiquity of man. Between the time, for example, when men had acquired the art of fashioning a club, of kindling a fire, and of making a flint knife, and that in which writing was invented, many ages must have passed. The conditions of quality of race and of local advantages must have been propitious to allow of the discovery having been at all; and so we find that it never has been made where these were not favourable.

"The Egyptians must have attained a large measure of civilization before they had invented symbolic or phonetic writing, and yet we find these in the most ancient of their monuments. . . . . . .

"From the sketch which I have now given of the formation of language, the conclusion is, I think, inevitable, that the birth of Man is of vast antiquity. He came into the world without language, and in every case had to achieve the arduous and tedious task of constructing speech which, in the rudest form in which we find it, it must have taken many thousands of years to accomplish."—L. H. March 26, 1861.

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OF

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PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

NOVEMBER 7, 1860.

William T. Blanford, Esq., of the Geological Survey of India; the Rev. Thomas Bigsby Chamberlin, Kirton-in-Lindsey, Lincolnshire; James Sparrow, Esq., Cymmau Hall, near Wrexham; and Richard Fort, Esq., Read Hall, near Whalley, Lancashire, were elected Fellows.

The following communications were read:—

1. *On the* DENUDATION *of* SOFT STRATA. By the REV. O. FISHER, M.A., F.G.S.

(Abstract.)

THE author first described the general features of the north-eastern portion of Essex, which consists, in part, of table-lands of gravel, with valleys cut into the subjacent London Clay and terminating seaward in tidal rivers, and, in part, of a gently undulating surface of London Clay, from which the gravel has been mostly swept clean away, except in places where flat outlying tracts of gravel still remain: these features extend also into the neighbouring county of Suffolk. The tidal rivers are evidently nothing more than a continuation of the valleys beneath the sea-level; and the same may be said of irregularly shaped inlets of the sea, like that behind Walton-on-the-Naze, which is a submerged valley in the part of the district where the surface is composed of London Clay.

The present configuration of such a district cannot be due, in the author's opinion, to the action of such causes as we now see in operation on the coast combined with a slow and continued elevation

of the land. Sea-waves cannot excavate long narrow inlets in homogeneous beds (such as Chalk), nor in horizontal beds, such as the gravel and clay of the district under notice; for the effect of sea-waves is to form long and approximately straight lines of cliff. Any curvature seen in such a line of cliff will be found to be due to some disturbing cause, as a variation in the resisting power of the strata, or the set of a current, or exposure of some parts to a greater force of wind, in which cases a bay will be formed, but not a long and winding creek.

If it were possible (which the author denied) for such valleys as those of the district under consideration to be formed by wave-action, their sides should present the appearances of degraded cliffs, masked with a talus of gravel derived from their crests; instead of which, their sides are rounded, the gravel-beds thinning out at the hill-top, and the clay exposed on the sides; nor is there any evidence of the existence of shingle-beds at the foot of the hills.

The only other agency of an *ordinary* character to which such denudation could be attributed seems to be tidal action, either at a time when the district was under water, or else during a gradual rise. But it seems impossible that the diurnal slow passage of a body of water to and fro over a sea-bottom could sweep out diverging narrow channels, carrying clean away gravel charged with large pebbles. Nor does the second supposition seem more favourable for the purpose, because the rapidity of the current in the tidal portions of the rivers, as we see them, is not competent to do more than to keep clear a comparatively narrow channel in their centres, the sides becoming covered with a deposit of mud (dry at low water), which, in the upper portions, forms alluvial tracts of meadow-land; nor does there seem any reason why the denuding power of the tidal rivers, during a *gradual* rise, should be greater than at present.

Mr. Fisher does not see any other way of accounting for such a form of surface as obtains in this district, and in many others composed of yielding strata, than by a superincumbent mass of water rapidly draining off from a flat or slightly dome-shaped area. Slight depressions, cracks, or lines of readily yielding materials would first determine the course of the streams of drainage; and these would cut channels which would be more or less completely scoured out according to the velocity of the water. Where the gravel-covering of such a district was cut through, the clay beneath would be channelled with a narrower and deeper valley,—the cutting power of the water being also assisted by the gravel hurried along with it; and where the gravel was wholly removed, the valleys would be wider, and the intermediate high ground rounded instead of being flat-topped. This character of surface is seen in the most eastern portion of Essex, and in nearly all clay-districts which are not low and flat.

The surface of the mud of a tidal river left dry at low water shows, on a small scale, a configuration identical with that described, and clearly due to the draining off of the superincumbent water when the tide falls. The only difference in the mode of action is that, in this case, sediment, instead of being swept away, after having been deposited, is not permitted to accumulate, so that a slower movement of the water is effectual daily to clear out the little valleys. These valleys in the surface of the mud are not formed by wavelets, which, at low water, begin to cut a miniature straight cliff at the margin of the mud.

These arguments lead the author to infer that the land must have been elevated by a sudden movement sufficient to have caused a rush of water from the raised portions to seek a lower level,—either the land being raised high and dry at once, or the sea-bottom raised, though still remaining beneath water. Such an elevation might be repeated again and again with intervals of submergence; and many of the phenomena connected with sunk forests, and other Pleistocene phenomena, seem to show that such conditions have really obtained in places at considerable distances apart.

The author stated that, in his opinion, escarpments, such as are so common among the secondary and tertiary strata, are rarely old cliffs, and he thinks that their rounded forms are due to such agency as he has described. In forming this opinion, he relies upon the following arguments:—

Cliffs in the softer beds run in approximately straight lines, or sweeping curves, while escarpments abound in nooks and combs running up into the hill-face (according to his view, gullies), down which the water has poured where it happens to have broken through the crest. Again, a line of cliff usually cuts off stratum after stratum, while the line of an escarpment usually follows the course of one stratum, and is entirely determined by the intersection of an approximately constant level with its undulating surface, that level rising slightly where the stratum is harder, and sinking where it is softer. Again, in an escarpment, like those of the Chalk, the mouths of the valleys run down into the plain below; but in a cliff many valleys are seen to be cut off at a level considerably above the beach,—a condition which would be clearly marked in a hill-side which had formerly been a cliff. The author cannot remember to have ever seen such a termination to a valley in the face of a Chalk or other escarpment.

Proofs of torrential action in Chalk-districts were referred to,—for instance, the perfect drainage-system of the dry valleys of Salisbury Plain and other extensive tracts of Chalk-downs, the loose flints filling the bottoms of such valleys, and the immense blocks of tertiary pudding-stone and "Druid-sandstone," scattered along the bottoms of Chalk-valleys, as in the Portisham and Bridehead valleys near Weymouth, and the Marlborough "Wethers" in Wiltshire. Mr. Fisher also thinks that he sees evidence of the friction of a great body of water rushing down a hill side in the manner in which vertical or nearly vertical strata are usually bent over at their exposed edges.

In estimating the denuding power of such a cause as that suggested, it is evident that the effects would be least of all on watersheds, great at the crests of valley-sides, and greatest of all in their bottoms, and that, where the velocity was diminished from any cause, sediment and brick-earth would be left behind. The author also sees an agency competent to deposit an extensive spread of brick-earth in the unlading of icebergs,—the coarser gravel sinking more quickly, and the finer particles and angular splinters less readily, and being liable to be stirred up and raised higher by every fresh shower of gravel falling upon them.

The author, having shown that the contour of the existing surface of our softer strata and other observed phenomena seem due to the sudden uprising of the land from beneath the sea, next inquires whether there have been more than one such movement, and whether these have been combined with periods of depression. Without entering into any detail on this part of the subject, he remarked that, the present contour being in the main the same as it was at the period of the great-mammalian fauna (only less elevated), there must have been a sudden elevation preceding that period, and that, during subsequent depressions, the valley deposits were formed in which the mammalian bones lie entombed, the valleys having been again partially re-excavated by the repetition of a sudden but less lofty upheaval.

Lastly, it was pointed out that sudden vertical movements of the surface on a grand scale are of as probable occurrence as those lesser movements with which we are historically acquainted ; for the earth's crust, to the depth of at least many miles, is rigid to such a degree that great changes of position in its parts cannot occur without actual disruption of the strata, as all faults testify. Its movements are not those of a flexible or semifluid envelope. Now, the pressure requisite to rupture nearly rigid strata will accumulate enormously before they yield to it, causing probably a slow and gradual movement from the want of absolute rigidity; but when once they are ruptured, they will be thrown up or down with a *sudden* movement. This will be true even on old lines of fault, for it will require a great and new accumulation of force to overcome the friction on the line of fault; but when once the rocks are set in motion, the resistance caused by the friction will be much less, according to a well-known principle in mechanics. Again, if lateral pressure, arising from failure of support, be the nature of the force which has elevated tracts of the earth's surface (which is the author's persuasion), such a pressure might accumulate very greatly without producing any vertical movement; but as soon as any local circumstance determined the course of an anticlinal or fault, the edges of the strata on one or both sides of that line would begin to be raised with reference to the neighbouring parts, and the pressure which, as in a bridge, had long existed in the plane of the crust without producing motion, would now act at an angle to the beds with momentarily increasing advantage, as in a bridge beginning to fall, tilting them into inclined positions, probably crushing them, and producing minor dislocations at the same time.

Thus, by mechanical considerations, the author is led to believe that the ordinary nature of the greater movements of the earth's crust must be sudden.

2. *On an* Undescribed Fossil Fern *from the* Lower Coal-Measures *of* Nova Scotia. By Dr. J. W. Dawson, F.G.S.

(Abstract.)

In a paper on the Lower Carboniferous rocks of British America, published in the 15th volume of the Geological Society's Journal, Dr. Dawson noticed some fragmentary plant-remains which he referred with some doubt, the one to *Schizopteris* (Brongn.), and the other to *Sphæreda* (L. and H.). With these were also fragments of a fern resembling *Sphenopteris* (*Cyclopteris*) *adiantoides* of Lindley and Hutton. Since 1858 the author has received a large series of better-preserved specimens from Mr. C. F. Hartt; and from these he finds that what he doubtfully termed the frond of *Schizopteris* is a flattened stipe, and that the leaflets which he referred to *Sphenopteris adiantoides* really belonged to the same plant. Mr. Hartt's specimens also lead Dr. Dawson to suppose that what he thought to be *Sphæredæ* were attached to the subdivisions of these stipes, and may be the remains of fertile pinnæ, borne on the lower part of the stipe, as in some modern ferns. This structure he regards as being something like what obtains in the Cuban *Aneimia adiantifolia*, as pointed out to the author by Prof. Eaton, of Yale College. No sporangia are seen in the fossil specimens.

Dr. Dawson offered some remarks on the difficulties of arranging this fern among the fossil *Cyclopterides*, *Nœggerathiæ*, and *Adiantites*; and, placing it in the genus *Cyclopteris*, he suggested that it be recognised as a subgenus (*Aneimites*) with the specific name *Acadica*.

The regularly striated and gracefully branching stipes, terminated by groups of pinnules on slender petioles, must have given to this fern a very elegant appearance. It attained a great size. One stipe is 22 inches in diameter, where it expands to unite with the stem; and it attains a length of 21 inches before it divides into branches. The frond must have been at least 3 feet broad. The specimens are extremely numerous at Horton.

The author then noticed that the long slender leaves so common in the Coal-measures of Nova Scotia, and hitherto called *Poacites*, though sometimes like the stipes of *Aneimites*, are probably leaves of *Cordaites*.

On some specimens of *Cyclopteris* (*Aneimites*) *Acadica*, markings like those made by insects have been observed; also a specimen of the *Spirorbis carbonarius*.

3. *On the* Sections of Strata *exposed in the* Excavations *for the* South High-level Sewer *at* Dulwich; *with Notices of the* Fossils *found there and at* Peckham. By Charles Rickman, Esq.

(Communicated by the Assistant-Secretary.)

(Abstract.)

In the autumn of 1859, open cuttings were made at Peckham, in connexion with the "Effra branch of the Great South High-level Sewer," for the "main drainage" of the metropolis south of the Thames; and in the following spring a tunnel (330 yards in length) was being constructed under the Five-fields at Dulwich. The beds exposed in both sections belong to the "Woolwich and Reading Series" of the Lower London Tertiaries (Prestwich).

Four shafts were sunk to facilitate the driving of the tunnel; and the following beds were exposed; but, as some of the beds are not persistent, but die out even within the extent of the tunnel, the several shafts differed as to the sections obtained from them.

1. Soil, 9 inches. 2. Loamy clay (probably London Clay); 12 ft. Not in shaft No. 1 (the most easterly), nor in No. 4 (the most westerly), owing to the convex surface of the ground. 3. Light-coloured clay; 6 to 9 ft. 4. Reddish sand; 5 ft. (not in No. 4 shaft). 5. Dark clay; 1 ft. 10 in. 6. Blue clay; 2 ft. (not in No. 4). 7. Dark clay; 1 ft. (in No. 1 only). 8. Paludina-bed; 6 to 15 inches. [Fossils: *Pitharella Rickmani* (Edwards), *Paludina lenta*, *P. aspera*(?). Bones and scales of Fish. Leaves.] 9. Cyrena-bed; 1 to 2 ft. [*Cyrena cuneiformis*, &c.] 10. Oyster bed; 1 to 3 ft. [*Ostrea tenera, O. pulchra, O. Bellovacina, O. elephantopus, O. edulina, Bysso-arca Cailltaudi* (?), *Cyrena cuneiformis, C. deperdita, C. cordata, C. obovata, Melania inquinata, Melanopsis brevis, Modiola elegans, Fusus*(?), *Calyptræa trochiformis, Corbula*.] 11. Loamy sand; 8 in. (in No. 4 only). 12. Red sand; 2 ft. (in No. 4 only). 13. Blue clay; 2 ft. 6 in. [Leaves.] 14. Dark sand; 8 to 28 in. 15. Blue clay; 18 in. to 9 ft. [Laminated; rich in Leaves, Lignite, Seed vessels. *Rissoa, Cyrena Dulwichensis* (Rickman).] 16. Dark sand; 2 to 4 ft. 17. Light-coloured clay; 2 ft. 6 in. (in No. 4 only). 18. Shell-rock; 4 ft. thick, sometimes intercalated with stiff blue clay. [*Cyrena Dulwichensis* (Rickman), *C. cordata, C. deperdita, C. cuneiformis, Melania inquinata, Melanopsis, Neritina, Pitharella Rickmani* (Edwards), *Unio, Teredines* in Lignite, Scutes of Crocodile, Fish-scales, Chelonian and Mammalian bones.] 19. Clay; 14 ft. and more: reached only by the main shaft, No. 3, which appears to have been sunk at the apex of a low anticlinal; the beds gently dipping away E. and W.

All the fossils appear in their respective beds both at Peckham and Dulwich.

NOVEMBER 21, 1860.

Robert Jones Garden, Esq., 63 Montagu Square; and Robert Home, Lieut. R.E., Royal Staff-College, Sandhurst, were elected Fellows.

The following communications were read:—

1. *On the* GEOLOGY *of* BOLIVIA *and* SOUTHERN PERU. By DAVID FORBES, Esq., F.R.S., F.G.S., &c.

[PLATES I., II., III.]

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Introduction.—IN laying before the Society a statement of the observations made during an examination of Peru and Bolivia, in the years 1857, 1858, 1859, and 1860. I may observe that the present memoir is to be considered as the first part of a report of the results obtained during my travels in South America during these years; and, consequently, it is believed that the conclusions here arrived at will have more weight when considered in conjunction with the observations on the geology and mineralogy of the neighbouring republics of Chile and the Argentine provinces, which subsequently I shall have the honour to lay before the Society,—more particularly as several of the geological formations not well developed or examined into in the district forming the subject of this memoir exhibit themselves much more characteristically further south.

Many points will be found not so elucidated or examined into as could be desired, and might appear to have been neglected; this, however, has not arisen from oversight, but is due to the great difficulties and frequently severe privations encountered in exploring a country in many parts entirely uninhabited or in next to a savage condition, and further by my having been limited as to time and pecuniary resources, and hampered by other occupations and by the political state of the country.

In the construction of the accompanying Map and Sections (Plates I. & II.), Nos. 1 & 2 of which give a good idea of the structure and formation of the different mountain-ranges of the Andes, the horizontal distances are laid down from the best local information which could be procured, and from data furnished by the Bolivian Government-survey lately completed. For the vertical altitudes in addition to those determined by myself barometrically, and occasionally by boiling-point and trigonometrical observations, I have employed some of the heights noted on Mr. Pentland's map,—and further the following series of observations made by a gentleman for some time my fellow-traveller, Captain Friesach, of the Austrian army, as given in the annexed Table.

Locality.	Elevation above sea in English feet.	Locality.	Elevation above sea in English feet.
Arica	20	La Paz (highest part)	12,270
Tacna	1,950	La Paz (Alameda)	11,930
Pachia	3,580	Millocato	8,150
Palca	9,700	Cotaña	7,990
La Portada	12,630	Hacienda de Illimani	10,010
Alto de Guaylillos	14,650	Santiago	8,940
Ancara	13,750	Rio de la Paz on entering Yungas	3,380
Uchusuma	13,910	Rio de la Paz below Toca	4,204
Rio Mauri	13,560	Yrupana	6,870
Pailumani	14,725	River below Yrupana	4,570
Chulluncayani (pass)	13,680	Culumani	6,460
Santiago de Machaca	12,770	Rio de Tanampayo	4,320
San Andres de Machaca	12,890	Coripata	6,360
Nasacara	12,710	Corioco	6,530
Surire	13,565	River near Corioco	3,925
Pacheta del Rio Colorado	14,210	Sandillan	7,040
Coniri	12,950	Highest point between Sandillan and Unduavi	11,830
Biacha	12 780	Copacabana	12,730
Unduavi	10,780	Puno (shore of Lake Titicaca)	12,630
Highest points between Unduavi and La Paz	15,630	Ariquipa (plaza)*	8,840
Tambillo de Laja	12,830	Summit of Misti, or volcano of Ariquipa*	19,876
Disaguadero	12,680		
Alto de Potosi	13,580		

* The height of the plaza of Ariquipa was determined by the Torricellian experiment, and found as stated above; the summit of Misti or volcano of Ariquipa was found to be 11,436 feet above the plaza by a trigonometrical measurement.

And lastly, in addition to these, the following Table of heights of mountains in English feet has been calculated from some of the results obtained by the recent Government-survey of Bolivia.

Mountain.	Elevation above sea in English feet.	Mountain.	Elevation above sea in English feet.
Illampu	24,812	Mururata	20,418
Illimani	24,155	Callinsani	20,530
Sajama (volcano)	23,014	Potosi	15,724
Coololo (Apolobamba)	22,374	Tunari de Cochabamba	15,608
Huayna Potosi	21,882	Hermoso de Aullagas	15,747
Cachacomani (volcano)	21,583	Portugalete	14,720
Quenuata } peaks of Tacora	21,252	Espejos	9,337
Chipicani } (volcano)	22,687	Misti (volcano of Ariquipa)	20,150

The strike and dip of the rocks, when not otherwise stated, are given with reference to the magnetic meridian.

In the arrangement of my notes it was found most satisfactory to classify them according to the geological age of the deposits in question, commencing with the most recent.

1. *Tertiary and Diluvial Formations of the Coast.*—The older Tertiary beds of shells so characteristic of many parts of the Chilian line of coast do not appear to present themselves from Mexillones northward to Arica; but we find at intervals shell-beds, containing exclusively shells of species now inhabiting these waters, elevated to a small height above the sea: I did not, however, observe any beds reaching an elevation of 40 feet above the present sea-level; and although the whole line of coast shows unquestionable signs of recent elevation, still the evidence is not so satisfactory, and appears to point out a much more irregular action than further south along the Chilian coast-line.

At Cobija I discovered a bed of shells in the immediate neighbourhood, to the south of the port, about 25 feet above the present sea-level; and, on examination, this was found to contain only species at present inhabiting these waters. Among these shells I recognized the following genera:—

Concholepas.	Fusus.	Patella.
Mactra.	Oliva.	Fissurella (2 species).
Venus (2 species).	Trochus.	Chiton.
Mytilus.	Turbo.	Serpula.
Tellina.	Turritella.	Balanus.

I found also fragments of an Echinus and bones of a Seal. Whilst digging in this bed, I came upon a small piece of wood in a decayed state, which evidently had been shaped by human hands, and bore marks of having been cut by a sharp tool, most likely of steel, as some of the cuts appeared much too defined to be attributed to a stone or other dull instrument.

On the rocks close to the town are some deposits of guano, which are being worked to advantage, although in quality and thickness much inferior to the guano from the Chinchas Islands pertaining to Peru. These deposits are situated at from 20 to 40 feet above the sea-level, and in appearance are very similar to the Chinchas beds on a small scale.

On the surface of these deposits, and also between the beds of the same, my attention was attracted by a crust or bed of a harder substance, of a light-brown colour, varying in thickness from a few inches to one or more feet, and possessing a semicrystalline and rather saline appearance, with occasionally a faint ammoniacal odour. On examination I found it to contain a large amount of ammonia in a state of combination; and, at the request of the Bolivian Government, it was analysed by Mr. Francis Ignacio Rickard, of Valparaiso, who obtained the following per centage composition:—

Water	12·45
Organic matter	17·48
Chloride of ammonium	30·20
Phosphate of lime	10·00
Sulphate of lime	0·80
Chloride of sodium	16·03
Sand	1·60
	98·56

From the above results it is evident that this substance had been produced by the action of sea-water, probably thrown up in the form of spray, on the guano-beds. The amount of ammonia contained in this material being much greater than in the unaltered guano itself, this substance, formerly thrown aside as worthless, is now exported in large quantities, under the name of "Huano petrificado," realizing a price considerably higher than the guano with which it occurs. The low elevation of these guano-deposits above the present sea-level, and their thickness, which is frequently not less than 10 to 15 feet, sufficiently prove that, in parts at least, they are of later origin than the shell-beds previously described. Other similar guano-deposits are met with at Mexillones, Algodon Bay, the newly discovered San Felipe Islands, and at various parts along the coast.

At several places along the coast the raised beaches are strongly impregnated with salt, which occurs both in the form of small layers, or imbedded, as well as irregularly distributed in the diluvial detritus. This is the case at Mölle, Ceremoño, and Patillos, all to the south of Iquique, and several other places. These saline deposits are found at the height of from 10 to 40 feet above the present sea-level; at the two first-mentioned places the salt is so abundant that cargoes have occasionally been shipped from them. On the top of the Morro de Arica, a hill about 500 feet above the sea, small superficial layers of tolerably pure salt, from ½ in. to 3 inches in thickness, are also met with; and the fissures on the side of the same hill are often found to be filled with veins of salt.

At Arica I was not successful in finding *Balani* and *Milleporæ* attached to the sides of the "Morro" hill, as described by Lieutenant Freyer*; and the many loose sea-shells met with on the sides and summit of the same I believe to have been brought there by the numerous sea-birds, probably assisted, on the south slope, by the action of the winds and shifting sands.

That no very perceptible elevation has taken place in the immediate neighbourhood of the Morro of Arica (or, if such an elevation had taken place, that it has been followed by a subsequent depression to nearly the same level) during the last 350 years, or since the Spanish conquest, appears from the numerous Indian tumuli found along the beach, for miles south of the Morro; many of these are not 20 feet, and some probably considerably less, above the present sea-level. That these tumuli have not been constructed since the

* Darwin's 'Geology of South America,' p. 47.

Spanish invasion may be inferred from the ornaments of gold found in them, along with the mummies, one of which I was informed had been found by Mr Evans, the Engineer of the Arica and Tacna railroad, enveloped in a thin sheet of gold.

Along the Coast of Chile, on the contrary, there is the fullest evidence to prove that, since the arrival of the Spaniards, a very considerable elevation of the land has taken place, over the greater part, if not the whole extent, of the line of coast.

North of Arica, if we accept the evidence of M. d'Orbigny and others, the proof of elevation is much more decided; and consequently it may be possible that here, as is the case about Lima, according to Darwin, the elevation may have have taken place irregularly in places; but at the same time a depression or submergence, as at Callao, could hardly have taken place without having destroyed these Indian tumuli, formed in the loose sand, and quite incapable of resisting the action of the waves, which produce a strong surf along this rugged coast.

With regard to the evidence of the rise of the land, deduced from the occurrence of sea-shells strewed over the surface of the higher ground further inland, it must be remembered that the numerous sea-birds which feed on shell-fish frequently carry their food to considerable distances from the sea, and likewise that shells are occasionally transported inland along with the sand in the shifting sand-dunes which are common enough along the coast; where the slope is gentle, as in the immense inclined plains to the north of Arica, this may frequently be the case. These sand-dunes appear to attain their greatest mobility during the hot season, when the parched sand rolls along impelled by the slightest breath of wind, and several times reminded me of the extraordinary mobility presented by silica and some other substances in a state of fine division when heated in a crucible or other vessel, especially if, as it were, provoked by the slightest touch of a rod.

An observer, travelling quickly over the ground, might easily be deceived, and regard as evidence of elevation the occurrence at some few spots of innumerable shells spread over a small area or patch in the midst of this desert landscape. On examination, these are found to be a land-shell (a species of *Bulimus*) about $\frac{3}{4}$ to 1 inch in length; and it is difficult to account for their presence in these spots, destitute of all vegetation, except on the supposition that they have made their appearance thus abundantly in years favoured with some showers of rain, which may have developed in these scattered spots a vegetation sufficient for their sustenance. I have noticed the occurrence of such spots covered with these shells in the midst of these desert-tracts, down to as far south as Choros Bajo, a little north of Coquimbo in Chile. Professor Philippi has also observed them at the Morro de Mexillones.

The coast from Mexillones to Arica is formed by a nearly continuous chain of mountains, rising abruptly from the water's edge, and attaining an average elevation of about 3000 feet, but diminishing in height towards their northern limit, the Morro of Arica, which does not exceed 600 feet above the level of the sea. An occasional narrow strip of sea-beach is seen bordering this range, and is composed exclusively of the débris of the mountains themselves, which, being in many places nearly perpendicular, expose to the spectator, passing along in the coast-steamers, a fine section of the shales, claystones, and imbedded porphyries which here represent the Upper Oolitic series, and are occasionally seen disturbed and altered by the intrusion of dioritic rocks of a later age.

At Arica, however, this range of mountains suddenly recedes from the coast, leaving an intermediate space, about 30 miles broad and extending as far northward as examined, occupied by gently sloping plains, evidently ancient sea-beaches, which rise to the height of about two thousand feet above the sea-level. These plains, being for the most part entirely destitute of water (as no rain falls in these regions), are consequently entirely barren, and present to the eye of the traveller a most desolate and arid appearance. When, however, as in the valleys of Tacna, Sama, and Azapa, a scanty supply of water does occur, the soil, noted for its surprising fertility, produces a most luxuriant vegetation of a semi-tropical character.

These plains are composed of sand, earth, and gravel, with abundant fragments, more or less rounded, of the porphyritic, dioritic, and volcanic rocks forming the coast-range of mountains which bound them to the eastward. Even after a most careful examination, no single fragment or boulder of any extraneous rock was met with; so that no drift-action appears to have assisted in the formation of these beaches, which appear due solely to the action of the waves beating against the former rugged line of coast.

In the Sections No. 1 and 2, Pl. II., which cut through this district, it will be observed that a volcanic formation, apparently contemporaneous, is situated in the midst of these plains, which does not bear the appearance of having been injected into the diluvial beds forming them, but rather to have flowed over them, or more probably to have been deposited on the top of them whilst still under water, in the form of a tuff or volcanic ash, and subsequently to have again been covered up by similar diluvial matter; a more detailed examination, however, is necessary to settle the question. I may mention that Dr. Vance of Tacna informed me that near the railway at that place the ground in a cutting was found to be burnt and altered, as if by igneous action; this appears to me as more probably due to still later volcanic activity.

The rocks of this volcanic formation are all trachytic, and frequently present a most striking similarity to the domite of Auvergne, being, like that, composed of quartz, black or brown hexagonal mica, and a weathered-looking felspar, and form some four or six beds, superposed one on another, and of an average thickness of about 10 feet each; these are either a white trachytic tuff, like domite, with abundant imbedded fragments of pumice, or a compact trachyte of a reddish or white colour and similar composition.

These trachytic tuffs form an excellent building-material, from the ease with which they are worked and shaped, and are very extensively employed for this purpose at Arica and Tacna. In the quarries of this rock near Tacna I discovered a mineral very much resembling allophane in external characters, but differing in only containing 28·49 per cent. of water: it occurs in fissures in the trachytes, forming veins of from a line up to some inches in thickness, and is probably derived from the decomposition of the felspathic element of the trachyte by the action of water.

2. *Saline Formations.*—Later in age than the Tertiary deposits, the saline formations so characteristic of this part of South America are not, as frequently supposed, merely confined to the country surrounding the port of Iquique, but appear at intervals scattered over the whole of that portion of the western coast on which no rain falls, extending further north than the limits of the map accompanying this memoir; whilst to the south they run entirely through the desert of Atacama, and even show signs of their existence further south than Copiapo in Chile, thus stretching more than 550 miles north and south; their greatest development appears, however, between latitudes 19° and 25° S.

They are generally superficial, but occasionally reach to some small depth below the surface, and then may be entirely covered over by diluvial detritus; they always, however, show signs of their existence by the saline efflorescence seen on the surface of the ground, which often covers vast plains as a white crystalline incrustation, the dust from which, entering the nostrils and mouth of the traveller, causes much annoyance, whilst at the same time the eyes are equally suffering from the intensely brilliant reflection of the rays of a tropical sun.

The salts forming these "Salinas," as they are generally termed, are combinations of the alkaline and earthy bases soda, lime, magnesia, and alumina, with hydrochloric, sulphuric, nitric, and carbonic acids, and occasionally with boracic, hydriodic, and hydrobromic acids,—and in combination present themselves as the following minerals in a more or less pure state:—Common salt, epsom-salt, glauber-salt, thenordite, glauberite, soda-alum, magnesia-alum, gypsum, anhydrite, along with chloride of calcium, iodide and bromide of sodium, carbonate and nitrate of soda, and in some places borate of lime and borax.

With the exception of the boracic acid compounds, the presence of which (as subsequently will be attempted to be proved) is due to volcanic causes, all the mineral substances found in these "Salinas" are such as would be left on evaporating sea-water, or by the mutual reactions of the saline matter thus left on evaporation on the lime, alumina, and organic matter found in the adjacent rocks, soil, and shell-beds; and as we have indisputable evidence of the recent elevation of the whole of this coast, and bearing in mind likewise that no rain falls in these regions, it appears very reasonable to suppose that all these saline deposits owe their origin to lagoons of salt water, the communication of which with the sea has been cut off by the rising of the land. When studying the structure of the mountain-ranges near the coast, it was also observed that, at all the large saline deposits, the chain of hills to the westward or sea side of the "Salinas" is of such a formation as might on elevation be expected to enclose a series of lagoons, which, by means of the breaks or lateral openings in the chain itself, could for a longer or shorter period keep up a tidal or occasional communication with the sea when high, which thus would pour in a fresh supply of salt water to make up for the loss sustained in the lagoons from the evaporation produced by the heat of a tropical sun. It is therefore not necessary to suppose that the great amount of saline matter generally present in these deposits is due to the salts contained in an amount of sea-water merely equal to the quantity originally contained in the lagoon, or, in other words, to the cubical contents of the lagoons themselves.

The occurrence of salt at different places along the coast at very small elevations above the sea, previously noticed, is no doubt due merely to the tidal infiltration of sea-water into the porous shingle and other beds, and its subsequent evaporation; and must not be confounded with the much greater and more elevated saline deposits further inland, which are met with at three very different altitudes above the sea, as follows:—

(1)	At, approximately, from	2500 to 3500 feet,
(2)	„	7000 to 8000 feet,
(3)	„	12,500 feet

above the present sea-level, and which appear to indicate three distinct and important changes in level in this part of South America.

(1.) The deposits situated at about 2500 to 3500 feet above the present sea-level include the important beds of nitrate of soda so extensively worked along this coast, and appear to run from latitude 19° southward into the northern part of the Desert of Atacama, showing themselves, according to the configuration of the country, at distances varying from 10 to 40 miles inland.

When in this part of the country, I had not time to make a more detailed examination of these saline deposits than was necessary to enable me to arrive at a conclusion as to their mode of formation and the origin of the nitrate of soda contained in them.

All the data that I could obtain appeared fully to confirm the "lagoon hypothesis" previously mentioned, and to prove that the original constituents of these beds had merely been such salts as would result from the evaporation of sea-water. The nitrate of soda and some other associated compounds are due to subsequent reactions, and consequent decomposition of the salt of the original deposit, mainly produced by the agency of carbonate of lime and decomposing vegetable matter.

The first step in the formation of nitrate of soda appears to be the decomposition of the chloride of sodium, or salt, by carbonate of lime (in the form of shell-sand, &c.) with the production of chloride of calcium and carbonate of soda, both of which salts have been shown to be present in quantity in the soil of these nitrate-grounds.

The carbonate of soda thus eliminated, when in contact with the mixture of shell-sand and decomposing vegetable matter which may be expected to result from the luxuriant vegetation around such a tropical swamp, and from the abundant marine plants in the lagoon itself, would realize the conditions of the French artificial nitre-beds, substituting only carbonate of soda for the carbonate of potash there used: we may consequently, with all fairness, expect a similar result in the production of nitrate of soda on a still larger scale.

This view appears much strengthened by the occurrence of wood, reeds, or rushes, and other vegetable matter in the nitre-grounds at but little below the surface, as well as from the general position of the nitrate of soda in the saline deposit, as it invariably occurs in the margin or outer edge of these, representing the shelving sides of the hollow or lagoon-basin, the central part of which is composed of layers of sea-salt only, frequently several feet in thickness.

In seeking for nitrate of soda, the searchers always look to the rising edge of such salt-basins, and further judge of the probability of finding the nitrate from a peculiar moist or clammy state of the ground, which is due to the presence of the chloride of calcium produced by the decomposition above explained.

The quantity of sulphates, and more especially of sulphate of lime, included invariably in these deposits might, at first sight, appear to the observer too great to suppose it due only to the evaporation of the sea-water; but I believe that this impression will be dissipated when he sees the enormous amount of gypsum removed in the form of hard white cakes, or sedimentary crust, from the boilers of the large distilling machines in use along this arid coast for producing from the water of the sea a supply of fresh water for the maintenance of the inhabitants, beasts of burden, and even the locomotive engines of the railways along this coast. It appears not necessary to suppose, as has been put forth, that the sulphates present have been formed by volcanic exhalations acting upon the beds of salt. The boracic acid compounds met with appear, however, to be due to this cause; and the borate of lime met with in such large quantities appears to be indirectly produced by the condensed vapours of volcanic fumeroles, many of which are still in full activity in this district.

The gaseous exhalations of these fumeroles have, I believe, never been submitted to a chemical examination; so that the presence of boracic acid has not actually been proved; it may, however, be inferred from the general resemblance which these fumeroles bear to those of Tuscany, the Lipari Islands, &c., where it is known to exist.

The borate of lime is found only on the more elevated part of this saline district, occurring on the eastern side of the same, where the rising ground begins to form the western slope of the adjacent cordilleras.

As volcanic action is developed on a grand scale in this mountain-range, such solfataras or fumeroles, forming lateral orifices on the side of the mountains, are very common; and we may expect that the waters coming down this slope carry with them in solution the boracic acid contained in the condensed vapours of these solfataras, which, coming into contact with the lime of decomposed porphyry-rocks, or the shell-sands of the plains below, would combine readily to form the nodules of borate of lime here met with.

It has been suggested that the nitrate of soda likewise owes its origin to similar causes; I consider, however, this view to be untenable where the vapours themselves, from the great amount of sulphurous and hydrosulphuric acid gases which they contain, are of so eminently deoxidizing a nature as to decompose any nitric fumes evolved by such volcanic action. I therefore believe the nitrate of soda wholly due to the chemical action previously expounded.

The saline deposits of this series do not rest directly on the rock itself, but on a beach more or less level, or hollowed out into lagoon-basins, and composed, as the present and the raised sea-beach previously described, of the débris of the adjacent porphyritic, dioritic, and volcanic rocks.

The deposits explored for nitrate extend from the river of Pisagua southward to Patillos, a distance of about 110 miles; but latterly new and extensive deposits have also been worked further south, inland from Tocopilla. There is, however, no doubt that they exist along the whole coast-line depicted on the accompanying map, at from 10 to 50 miles inland; the borate deposits, however, appear to recede from the coast, as they occur more to the south, and strike to the eastward, following the line of volcanic action, indicating thereby their connexion with the same.

(2.) The series of saline deposits next in elevation are situated at from 7000 to 8000 feet above the level of the sea, and are developed on a grand scale in the northern part of the desert of Atacama,—the great "Salina de Atacama" extending 100 miles or more from S.E. to N.W., with a breadth of 20 to 30 miles, and the lesser "Salina de Punta Negro" still further south (about 30 miles long and 12 broad)—two examples of immense salt-plains, apparently resulting from the drying up of such lagoons as those before described.

Not having made a personal examination of these, I am not in a position to give any detailed account of them; in fact, they are only known in name and extent, and have never been examined.

(3.) At an altitude of about 13,000 feet above the sea, saline matter is found to occur in a manner similar to that of the last-mentioned deposits. In Section No. 2 (Pl. II.), at "Laguna Blanca," extensive plains and salt-lagoons are found,—the latter still existing as lagoons, since they are now situated on the extreme borders of the rainless region, whereby the loss from evaporation is supplied, in part, by the rain which falls; and thus we generally find extensive plains covered by white crystalline salt, forming the circumference of some small and generally shallow lake, deserving only the name of a swamp except in the rainy season of the year. This saline formation, I believe, is seen more or less developed all the way to Oruro, and thence over the saline plains of Sora-Sora, it extends much further south, but, like the last, has not as yet formed a subject for more minute examination, and, from its occurring in districts exposed to a heavy annual fall of rain, is naturally not so characteristic in its development as the two previously described formations, although at the same time it presents some very striking features, and in some respects strikingly reminds us of its supposed lagoon origin.

3. *Diluvial Formations of the Interior.*—The saline deposits last noticed are situated in the midst of what may be termed the great Bolivian plateau, having an average altitude of fully 13,000 feet above the sea, and bounded to the west by the Upper Oolitic rocks of the coast-cordilleras, whilst to the east it abuts against the Silurian range of the true Andes. This plateau is not uniform in its mineralogical nature; and when viewed in section from east to west, it shows considerable diversity of composition, arising from the ranges of hills which intersect it all bearing nearly north and south, and thus dividing it into so many longitudinal valleys (see Pl. II.).

These valleys are generally occupied by nearly level plains, formed of the gravelly spoil produced by the wearing down of the bounding ridges, with which they are consequently identical in lithological composition. The ridges themselves seldom attain a greater elevation than 2500 feet above the plateau, and are generally under this height; but occasionally volcanic cones thrust themselves up to more than 6000 feet above the plain, and consequently attain an elevation of fully 20,000 feet above the sea-level.

The character of this plateau is well shown in the Sections Nos. 1 and 2 (Pl. II.), by a reference to which it will be seen that it may be separated into three divisions—western, central, and eastern (Oolitic, Permian, and Silurian, according to the nature of the rocks originating the diluvial accumulations which fill up the intermediate basins or valleys).

The most western of these is essentially composed of Upper Oolitic detritus, with an occasional block of diorite, and in places abundant volcanic débris from the neighbouring eruptions. They are covered with but a very scanty verdure, if not entirely barren, and incrusted with saline matter, and are generally either entirely destitute of water, or possess some few springs at great distances from one another and of abominable quality—frequently, as at Rio de Azufre (Section No. 2), not potable, and even causing death to the animals which drink it, as sufficiently proved by the bones of mules, llamas, &c., scattered along the banks. At most places the water generally produces bad effects to those unaccustomed to it, even when it is comparatively tasteless.

From an examination of the waters from several localities, I may observe that in one or two cases it was perfectly astonishing what an amount of saline matter might be present in water which might be termed "palatable," but which produced strong purgative effects; on examination, such a water from the desert of Atacama was found to contain a very large amount of the sulphates of soda and magnesia (Glauber and Epsom salts), associated with common salt and carbonate and sulphate of lime; and I can only suppose that the bitter taste which the amount of sulphate of magnesia (Epsom salts) present would alone produce had been neutralized or concealed by the admixture of the other salts.

In the midst of these plains at Ancara, I noticed some recent conglomerate-beds, of a brown colour, composed of small and very angular pebbles, and more like a breccia than a true conglomerate. They were of very small extent, and had an apparent strike nearly N. and S., with a low dip to eastward.

The central division of this diluvial formation is distinguished at first sight from either of the others by the redness and sandy nature of its soil, showing at once its derivation from the Permian or Triassic sandstones and marls; occasional patches are covered by volcanic detritus where the sandstone hills have been disturbed by the intrusion of the trachytic rocks, well illustrated in Section No. 1. The plains thus formed are well watered and frequently marshy, and are cut up by numerous rivers, at least in the northern part of the district here described*; we do not find the surface-water saline, as is invariably the case in the western division; but occasionally, as for example at Santiago and at San Andres (both on Section No. 2), we meet with brine-springs, which furnish the inhabitants with an abundant and cheap supply of culinary salt of excellent quality, by simply allowing the water to evaporate in the open air from the heat of the sun. These brine-springs are most probably due to salt-beds situated at greater depths in the sandstones of the formation itself, and not to be attributed to saline deposits of more recent origin.

The third or eastern division of this plateau is, in its turn, so different in character from either of the preceding, that it is at once recognized when encountered.

In Sections Nos. 1 and 2 (Pl. II.), this formation is seen as a great plain abutting to the east against the Silurian rocks of the highest range of the Andes, to the débris of which it owes its origin; whilst to the westward it is confined by the range of low hills of Devonian strata which separate it from the central division of this diluvial formation. The intermediate basin, occupying the space between these Silurian mountains and Devonian hills, is filled up to the level of the plain by an immense accumulation of clays and gravels, with larger pebbles and boulders of Silurian and granitic rocks,—the former being represented by grauwackes, indurated sandstones, clay-slates, and shales, which latter occasionally contain fossils of Silurian age.

Where, as in the valley of the river of La Paz (which from its abruptness might almost be termed a ravine), a section of this basin is disclosed (Section No. 2), its surprising magnitude is seen, as in this place. The thickness, reckoning from the level of the plain

* I may here mention that in a spring at Comanche, the water of which appeared to feel slightly warm on immersing the hand, I found numbers of a small univalve shell; and on submitting them to the inspection of Professor Philippi, of the University of Santiago, in Chile, he considered them identical with his *Paludina Atacamensis*, which he discovered in a tolerably hot spring at Tilopozo, in the northern part of the Desert of Atacama.

above down to the Alameda of La Paz, was found by measurement to be 1650 feet, consisting of alternating beds of grey, bluish, and fawn-coloured clays, gravel, and shingle-beds, along with boulders of clay-slate, grauwacke, and granite, frequently of enormous size, and well rounded as if by the action of water; the beds are nearly horizontal, or dip to the south. About 300 feet below the surface of the plain, there is seen in this section a bed of trachytic tuff, evidently volcanic, and about 20 to 30 feet in thickness. This is visible at a great distance as a white band, running along the precipices encircling this valley or ravine, and appears to be contemporaneous with the beds of clay, gravel, and boulders, which, with this solitary exception, form the rest of this diluvial accumulation, and which, except in the uppermost beds, do not contain, as far as I examined, any volcanic detritus.

No trace whatever of volcanic activity being found anywhere in the neighbourhood of La Paz, I was for a long time greatly puzzled to account for the occurrence of this very peculiar bed in the midst of diluvial strata. The general inclination of the beds themselves, dipping to the south, indicated that they had been drifted from the north or north-east, and they appeared to become narrower towards Lake Titicaca, near which I found the large volcanic outburst of trachytic and trachydoleritic rocks shown in Section No. 1, and from which doubtless the tuff forming these beds had emanated, and had been carried down by aqueous action, and deposited as a sedimentary bed in the series of clays, gravel, &c., forming this great thickness of drift.

The total thickness of these beds below La Paz must certainly exceed 2000 feet, and probably reaches 2500 feet, being certainly one of the most finely developed examples of this class of deposit, both as to magnitude and superficial area. I am unable to assign any correct limits to this formation, which appears to extend from north to south through the entire length of Bolivia; to the north, or towards the Lake of Titicaca, it appears to diminish in thickness, and may possibly wedge out entirely. The beds seem to have a general, but slight, dip to the southward.

I may here mention that in a small pool of water at a place called the Tambo de Perez, about half-way between La Paz and the Lake of Titicaca, I found numbers of a small fresh-water bivalve, which Professor Philippi, of the University of Santiago in Chile, kindly examined for me, and pronounces to be the *Cyclas Chilensis* (D'Orbigny), found first near Conception in the south of Chile, where it is common, according to Dr. Philippi, both in Valdivia and Puerto Montt. In these localities this shell is found at but a small elevation above the sea-level, in the coldest inhabited part of Chile; whereas in Bolivia, as above stated, we find it under the tropics, but at an elevation of about 14,000 feet above the sea; so that we may here regard this excess in elevation above the sea-level as equivalent to the difference of about 40 degrees in latitude.

Amongst the clay-beds of this diluvial formation, near La Paz, as also at the foot of Illimani and near Poto-Poto in the valley of the

River Chuquiaguillo, I found interstratified a bed of carbonaceous matter, approaching to lignite. In many parts this appeared as if wholly composed of carbonized marine or marsh plants, resembling rushes, reeds, and algæ; but I likewise found one or two pieces of unmistakeable lignite or carbonized wood. At all these places it is, probably, that it is but one and the same bed which appears at Poto Poto; this bed does not attain a thickness of more than from 6 inches to a foot. At the foot of Illimani it is, however, of much greater thickness.

A chemical examination, which I made of several of the clays from these strata near La Paz, showed that they contained but a mere trace of lime, as might be expected, knowing that the Silurian rocks of the high Andes, from which they appear to have been derived, contain but traces of limestone.

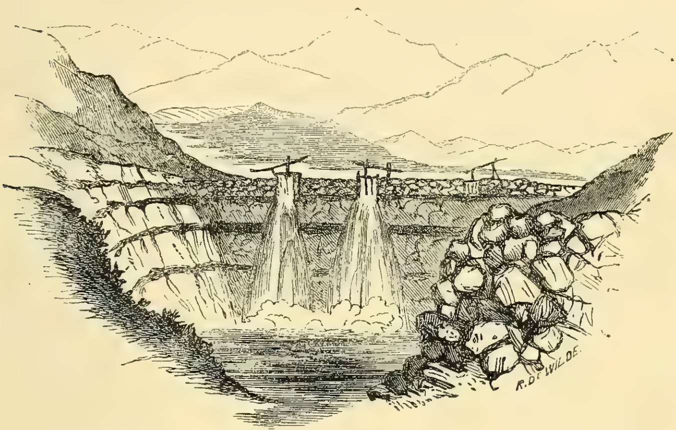
As the Silurian origin might indicate, this formation is everywhere eminently auriferous, and has been both since, and probably even before, the time of the Incas very largely explored for gold. The great quantities of gold found in Peru at the time of the Spanish conquest, had in greater part, if not wholly, been derived from these diluvial accumulations.

The rabbit-like burrows made by the Indian gold-workers into the more auriferous beds are everywhere visible along the sides of those valleys where a supply of water was not too distant to prevent these workers from transporting the auriferous earth for the purpose of working it: and frequently later explorations have disclosed the mummies or skeletons of unfortunate Indians, who have perished in these narrow and tortuous holes, from the falling in of the superincumbent earth, and been buried along with their mining implements.

This system of working is now entirely abandoned, and the mode of operating is very different at present, and can easily be understood from the annexed sketch (fig. 1), which may be supposed to represent a general view or sketch-section of the operations carried on at the gold-washings of Chuquiaguillo, near La Paz, belonging to Mr. Saienz of that city.

As will be seen in this sketch, the valley is, in the first instance, completely closed up, and the course of the river stopped, by a rude wall or dam of stones and earth, provided with sluices, and having a portion of the wall seen to the right hand somewhat lower, in order to carry off any overflow of water which otherwise might disturb the workings. A longitudinal excavation is then made close up to the one side of the valley, and of such breadth as can be conveniently carried on by the number of hands at disposal; and, in making this, the large boulders and stones, too heavy to be carried off by the rush of water, are piled up to one side, whilst the earth, gravel, and clay are merely loosened and flushed off by the water turned on from the sluices, allowing the force of the stream to carry them down the river. On arriving at the several successive auriferous beds, which are known from previous trials, and which are denoted by the dark bands running horizontally across the excavation, as seen in the sketch, more care is taken, but the whole of the auriferous earth is likewise flushed off, and, being so much heavier than the rest, deposits itself at but a little distance from the workings, where it is collected and subjected to repeated washing in a trough until nothing but the gold-dust remains behind.

Fig. 1.—*Sketch of the Gold-washings on the River Chuquiaguillo.*



This excavation is deepened until the lowest available auriferous stratum has been reached, and then abandoned, in order to carry on the same operation parallel to it; the boulders and stones met with in the new working are thrown into the old excavation, and such excavations are continued right across the valley. In a valley of considerable breadth it would be impossible, except by employing an immense number of hands, to open out and lay bare the whole of the auriferous ground in one excavation.

The auriferous strata occurring in these diluvial accumulations are, in Bolivia, generally known by the name of "Veneros," and appear to correspond to what are technically termed "floors" by the gold-diggers of California and Australia, being, as it were, the floor or clay-bottom upon which the gold-dust had settled down, subsequently covered up by alternating beds of coarser sand, gravel, and boulders: above this a similar floor and coarser beds might in their turn be found, as in the sketch of the washings on the Chuquiaguillo (fig. 1): and where these diluvial strata are of still greater thickness, a proportionate number of "veneros" are generally found to occur.

These "diggings" are, as might be expected, confined to the sides of valleys and beds of rivers which contain water* sufficient for washing. The celebrated workings of Tipuani and those in the

* The rivers of this part of the world are too frequently "Rios Secos," a Spanish term which is generally adopted.

Yungas appear also to belong to diluvial accumulations of this same geological age.

The valley of La Paz, being entirely cut out of this great diluvial formation by the action of the river which traverses it, is, as might be expected, often exposed to considerable landslips during the extremely heavy rains of the wet season: when residing there, I witnessed such a landslip, which blocked up the valley and caused it to be inundated to a considerable distance by the damming up of the river. In many parts also the action of the rains and small rivulets formed by them, cutting through these immense clay and gravel strata, forms a most striking and picturesque landscape. The slope of the valley of La Paz, for example, is seen cut up into innumerable ravines of great depth, whilst pinnacles of more than 60 feet in height will be left standing in great numbers and of all variety of form, frequently quite isolated, and, from their slender proportions, often looking like needles or pillars formed artificially: the sides of these show a very pretty section of the variegated clays and gravels that previously had formed the beds from which these had been carved out and left as standing mementos.

At the same time the roads will be hollowed and traversed by chasms, natural arches, and subterranean holes, of the strangest form, too frequently proving dangerous to the rider passing over them. These effects, in general only seen in miniature elsewhere, present themselves on such an immense scale as to leave a very decided impression on the observer.

4. *Volcanic Rocks.*—Although these rocks are occasionally more recent than any of the deposits previously treated of, and are in places, as from the volcano of Ariquipa, &c., ejected at the present day, still it is preferred to consider them in this sequence, from the epoch so assigned to them being one in which they appear to have attained their maximum development, and in which they have produced such grand changes in the configuration and level of this part of South America.

They are, as seen in Section No. 2, contemporaneous with the great diluvial formations at La Paz, and possibly may there represent an early Tertiary period, from which time to the present they seem to have been in more or less continuous activity, and to have presented themselves with the same general characters and under very similar circumstances.

M. d'Orbigny* has classified these rocks as of two distinct ages, known by their differing slightly one from another in their state of aggregation and the presence of augite. An attentive study of these volcanic deposits showed how difficult it was to draw any such defined line of demarcation in rocks which, as before stated, possess all main features in common; and in fact seemed to show that M. d'Orbigny's two classes are in reality (at least in many cases) one and the same, presenting slight differences in mineral character on

* M. Pissis also. Annales des Mines, 1856: "Recherches sur le Système de Soulèvement de l'Amérique du Sud."

account of the one being subaërial, or injected between the strata, whereas the other has been subaqueous, and in consequence is frequently met with as a tufaceous bed interstratified with other strata of acknowledged sedimentary origin. As both such rocks might be at one and the same time in course of formation, this difference can hardly be looked upon as indicating a difference in geological age.

The Sections Nos. 1 and 2 (Pl. II.) are fully sufficient to show how important a part volcanic action has taken in altering the contours of the mountain-ranges here traversed: probably in no part of the world do we find volcanic phenomena more energetically developed or affecting so great a territorial area.

As will be seen from the accompanying Map (Pl. I.), the volcanic rocks forming at the north the active volcano of Ariquipa and others in that neighbourhood are cut through in Section No. 1 (Pl. II.); and still further south, in Section No. 2, they form the volcano of Tacora or Chipicani, 19,740 feet above the level of the sea; still further south they form the more or less active volcanos of Sajama (22,915 feet), Coquina, Tutapaca, Tucalaya, Isluga, Calama, Atacama, Licancau, Toconado, Llullayacu, and others intermediate, which, in conjunction, form an almost continuous range of volcanos into that part of the Desert of Atacama pertaining to Chile, through which country we find this volcanic range appearing at intervals; and still more to the southward it is doubtless in connexion with the volcanos of Patagonia, the north of Magellan's Straits, and Terra del Fuego. As will be seen from this, the general direction will be nearly north and south; and, from a study of the line of fracture and position of the intruded rocks, it would appear that the subterranean force here exerted had its centre to the west of this line, and had acted at a high angle from the west towards the east.

The beds of trachyte and trachytic tuff which are seen interstratified in the raised beach at Tacna, Azapa, &c., and also in the great diluvial formation of La Paz, have already been noticed. Further east, in Section No. 1, at Tarocache, a very peculiar volcanic conglomerate and tuff stratum was met with, remarkable for the columnar structure which presents itself on a very large scale on the side of the nearly perpendicular hill under which the road passes; the columns are so well developed, that, seen from the road, they look as regular as similar basaltic formations. On Section No. 2, at Palca, and still further east, at Questa Blanca, deposits on no great scale, of a white crumbly trachytic tuff, composed of more or less decomposed felspar, with quartz and hexagonal black or brown mica-plates and an occasional speck of augite, are met with as more or less horizontal beds, resting unconformably on the highly inclined strata of Liassic shales, &c.; both of these deposits, as well as the previously mentioned one at Tarocache, appear to be remnants of some more extensive bed of sedimentary origin formed of volcanic tuff and ashes from the volcanos situated still higher up the range.

In Sections Nos. 1 and 2, the great volcanic formation is seen a little further to the east, forming a high ridge or range of peaks averaging from 16,000 to 19,000 feet above the sea, visible from the coast, and generally having their summits coated with snow. In both Sections (Nos. 1 and 2) this range breaks through the Upper Oolitic series of shales, claystones, porphyry-conglomerates, tuff, and mbedded porphyries, and above Tarata has enclosed, or at all events dislocated, a large mass of these (seen in Section No. 1), in which several strings of copper-ores were noticed: the volcanic rocks here are continuous with those forming the volcano of Chipicani, seen on Section No. 2. This I have not ascended; I have only passed along the sloping plain at its base, the fragments of volcanic rocks on which left no doubt of its character. Before coming to Uchusuma I noticed a step-like series of trachytic tufaceous beds, so characteristic of this rock when met with in this part of the world, each step being apparently a bed of great extent, and varying in thickness from 10 to 30 feet: these are called "Ancomarca" by the Indians, from their white colour; they extend nearly to the River Caño, at which place their formation is well illustrated in Section No. 2. It would appear that they had been erupted through long narrow fissures or dykes and poured out over the country either as lava or, in some cases, as light volcanic ashes* emitted from the fissures, and deposited on the ground in their neighbourhood, where they have gradually consolidated into beds. At the Rio Caño two such fissures are seen, bearing nearly E. and W., and dipping 15° to the south, the more western of which can be traced for miles as far as the eye can reach, appearing as a narrow white band or ridge, elevated one or more feet above the ground, from its having resisted the atmosphere better than the porphyry-conglomerate through which it breaks. Sometimes, as at the Rio Mauri (Section No. 2) and Chulluncayani, these are seen capping the rocks, and presenting the appearance of white bands running along the precipitous flanks of the hills or ravines; at Pisacoma, Section No. 2, this is also seen, as well as the occurrence of similar bands injected between the beds of the red sandstones, and sometimes continuous for miles. As might be expected, the contrast in colour between these white trachytic rocks and the dark-coloured Oolitic or Red Sandstone rocks which they cap, or with which they are interstratified, frequently at an immense height up the nearly perpendicular sides of these rugged and barren mountains, is wonderfully characteristic, and visible at very great distances. When breaking through sedimentary rocks, these lateral eruptions appear in general to conform themselves to the line of stratification, evidently from this affording less resistance, and there being always a much greater tendency for a fissure or crack to follow this line than to break through the more solid beds.

Between the Oolitic series and the Permian or Triassic sandstones in Section No. 1, as well as between these last and the Carboniferous basin of the Lake of Titicaca, we find great tracts which to the passer-by present to the eye no signs of other rocks than volcanic, and are occupied by plains or low rounded hills, covered on the surface with abundant fragments of trachyte and trachydolerites or with volcanic alluvium, composed of grains or sand of colourless quartz, white or co-

* Frequently containing much pumice.

lourless felspar, hexagonal brown or black mica, and black or green-black crystals of augite, along with black magnetic oxide of iron, always found as a black magnetic sand when a magnet is drawn along the surface. In passing over these plains the traveller's attention is attracted, and his eyes dazzled and wearied, by the glittering specks arising from the reflection of the sun's rays from the numerous small quartz-crystals strewed along the surface. The solid volcanic rock is only occasionally met with; but hillocks are frequently seen which, judging from their surface at least, are entirely composed of larger masses or fragments of trachytic and trachydoleritic rocks. I do not consider these tracts as representing spaces occupied by the actual protrusion of volcanic matter, but in some cases regard them as only covered by sheets of such trachyte or trachydoleritic lava poured out from longitudinal dykes or fissures such as before described; and in other instances I even suppose them to be, in part at least, composed of volcanic ashes, tuff, or débris, spread over the surface by the action of water*.

As far as I could observe, the volcanic rocks do not anywhere appear breaking through the Silurian rocks; but in the north of Bolivia they are seen on the Map (Pl. I.) as cutting through the Devonian series near Hachecache and the Lake of Titicaca, a distance of more than 200 miles from the coast in a direct line: this I believe may be considered as the most inland point at which volcanic phenomena make their appearance on the western side of the high Andes. These rocks are all *in situ*, and are true trachydoleritic and felspathic lavas which have broken through the strata, part of which are in consequence greatly altered. These lavas are further characterized by the peculiar parallel arrangement of their mineral constituents, which give that ribboned appearance due to the striæ of fusion, such as are frequently seen in more recent lavas.

Professor Philippi having allowed me to examine a series of rock-specimens which he had procured during his travels in the desert of Atacama, I found that the volcanic rocks from Punta Negra, Tilopozo, Toconado, Sorras, Atacama-Alta, &c. were all trachytes or trachytic tuffs, and precisely identical in mineral composition and character with those from the more northern part of Bolivia which I have more specially examined; and from his notes, which he also kindly placed at my disposal, I find that from San Bartolo to Chañaral Bajo, a distance of about 250 miles, we have, as in Sections Nos. 1 and 2, a ridge formed by an almost continuous series of lateral outbreaks of such lava cutting through and flowing over the dioritic rocks and the porphyries, shales, &c. of the Oolitic series, which, as at Chaco and other places, contained in abundance Liassic *Posidoniæ*, *Ammonites*, &c.

The large lateral overflow of lava, from 25 to 30 miles long and several miles in breadth, extending from San Bartolo to San Pedro

* The plain at Santiago de Machaca, Section No. 2, contains much volcanic alluvium, as described, and seems rather to have been formed by such aqueous action. I did not find sufficient evidence for colouring it as a sheet of trachytic lava, as M. Pissis has done.

de Atacama, is composed of a trachyte or trachytic tuff, consisting of a white or flesh-coloured felspathic base, in which are imbedded plates of hexagonal brown or black mica, and numberless perfect crystals of colourless quartz from $\frac{1}{4}$th to $\frac{3}{4}$ths of an inch in length and having both ends terminated by perfect pyramids; these quartz-crystals can be extracted from their matrix, leaving a perfect mould in the felspathic base, from which they had evidently been the first mineral element to crystallize.

The trachytic lavas of the other parts of Bolivia and Peru very commonly show the quartz so crystallized; and in Sections Nos. 1 and 2 such are also met with, but not so beautifully developed as from San Bartolo southwards. Both at Atacama-Alta, Toconado, Sorras, Tilopozo, and other places along the line of Dr. Philippi's route, the specimens also showed characteristic trachytic tuffs and trachydolerites. In some of the tuffs the quartz present was in the form of rounded grains, as if due to attrition, or more resembling the effect which igneous action would produce in rounding off the edges by fusion, or by the solvent action of some fluid compound in the lava acting on the crystals once formed.

There is but little variety met with in the volcanic rocks of this part of the world, those of Peru, Bolivia, and Chile being all very similar in external appearance and mineral composition: the principal rocks are trachytes, trachytic tuffs, trachydolerites, dolerites, and felspathic lavas.

The trachytes and trachytic tuffs are generally white, but occasionally of a pale flesh- or fawn-colour, and are composed of a felspathic base, probably only consisting of one felspar (frequently crystallized, but also met with in a more amorphous form), colourless quartz (always crystallized, and often, as described, in perfect crystals), and black or tombak-brown mica crystallized in small hexagonal plates, seldom more than $\frac{1}{10}$th of an inch across. From the smaller lateral fissures the eruptions are generally composed of trachytes; but it is extremely difficult to draw a line between the true trachyte and the trachytic tuffs formed from them, and which occasionally are met with as solid and compact as the original trachytes themselves, and only to be distinguished from the latter by the somewhat decomposed appearance of the felspar, the bronze-brown colour of the originally black mica and the included fragments of pumice, &c.*; they are, however, in general much more open or porous in texture, and often crumbly, so as frequently to be mistaken for white sandstones. They are everywhere largely quarried and used as building-stone, being durable and very easily worked; when cut into hollow cones they are used as filtering-stones for purifying water for domestic use, for which purpose they are well adapted from their porous texture. I have reason to suppose that these trachytes have frequently been

* I had expected that the decomposition of the felspar would probably give rise to the formation of alkaline or earthy carbonates in these trachytic tuffs, and so afford a means of distinguishing them from trachytes; in this I was disappointed, as several trachytic tuffs from Tacna, Azapa, La Paz, &c., on being treated with acids did not effervesce at all.

ejected whilst in a pasty state, after the quartz had crystallized and the temperature of the whole had become much lower than the fusing-point of the entire rock itself.

The trachydolerites differ from the trachytes only in having, in addition to the felspar, quartz, and mica of the latter, crystals of dark-green or black augite scattered through the mass, in which also the quartz does not appear so predominant; and the rock is frequently considerably darker in colour. They form eruptive masses much greater than the pure trachytes, and are seen largely developed on Section No. 1 at Batalla and Yunguyo.

Doleritic rocks I have only met with *in situ* on the eastern declivity of the volcanic range of mountains between Tarata and the River Mauri in Section No. 1; and in Section No. 2 they are seen as abundant large blocks scattered over the slope of the volcano of Chipicani. From their very compact structure, conchoidal fracture, and dark bluish-grey or greenish-grey colour, they much resemble basaltic rocks; but their crystallization is so close-grained that I could not distinguish whether olivine was present; and, in fact, their mineral composition is not recognizable by the naked eye, so that their exact nature is open to inquiry: they do not appear to form any great proportion of the mass of volcanic rocks here developed.

The greater volcanic rocks, at least those which have broken through as lava and remain *in situ* as a compact rock, are composed of a crystalline felspathic lava, much more basic in chemical character than the others (possibly if we except the dolerites), and which appear to be almost exclusively composed of one or more varieties of felspar. They generally possess that peculiar parallel structure frequently met with in all volcanic rocks, whether recent or more ancient, and apparently due to a cause similar to that of the striæ of fusion visible in glass. This striated appearance is frequently rendered more apparent from the different layers being of different shades of colour, reddish or whitish grey, or, as at Pailumani, where these rocks are very largely developed, of a dark grey colour, probably from some admixture of augite in a non-crystalline condition and intimately diffused through the felspathic mass so as not to be visible to the naked eye. These rocks sometimes are also found to contain a little mica or augite, in plates or crystals, but appear in general to be free from quartz. They are developed on a large scale between Hachecache and Tiquina, Section No. 1, and also at Pailumani, Section No. 2, where they appear to form the entire mass of the eruptive rock.

In neither Section No. 1 nor No. 2 do we cut across any volcano at present in activity, nor meet with any lava or scoria likely to have been produced more recently; at but very short distances, however, both to the north and south of these lines of section, volcanos were observed in activity; and during my residence in the country, the "Misti" or Volcano of Ariquipa was in eruption. In the immediate vicinity of Tacora various Solfataras might be seen in action; and their action on the Oolitic and Porphyry series was visible at great distances, on account of the brilliant yellow, red, and brown colorations produced by the action of the volcanic fumes and acid vapours on these rocks, and the formation of various salts of iron, lime, &c. To the south of Tacora I noticed an evolution of smoke, as if from a similar solfatara; and my fellow-traveller, M. Friesach, informed me that, when he passed in October 1859, a volcano situated a little to the right of Sajama, and apparently one of the three cones named Las Tetillas on the new map of Bolivia by Mujica and Ondarza, was observed by him in eruption, vomiting forth immense volumes of smoke, and apparently also lava, not from the cone itself, but from a lateral orifice situated at the base of the cone. The volcano of Tutapaca is also situated in this direction, and is still in activity; and near this place M. Modesto Bazadre informs me he visited a valley containing several hundred of little volcanic cones emitting boiling water, and in many respects resembling the Geysers of Iceland; like these latter, the cones around the orifice of ejection are formed by the deposit from the water itself.

Although we find the volcanos of this part of South America presenting themselves as lofty cones, rising high above the surrounding plateau, we do not observe in general that crater-form of summit so usual in mountains of this class in other parts of the world: we certainly find, as in the Misti (or Volcano of Ariquipa), some well-developed small craters; but these seem rather to have served as so many safety-valves to the volcanic boiler, and to have played but a very subordinate part in furnishing the great amount of lava and other volcanic matter here met with, which appears in greater part, if not entirely, to have made its way up through the great lateral fissures or openings (similar in many cases to dykes) which appear to have poured forth sheets of lava, covering vast areas of the surrounding country. This class of eruptions appears peculiarly characteristic of the Pacific side of South America, where they seem to attain a magnitude unknown in any other part of the world. The southern part of Bolivia shows such lateral eruptions, covering the ground with trachytic lava for more than 300 miles continuously; and in the northern part, as seen in Sections Nos. 1 and 2, the same occurs,—some of these eruptions appearing to proceed from such lateral dykes or fissures, at the lowest estimate not less than fifty miles in length, if not much more.

The volcanic rocks here described are strikingly distinct from those which I met with during my examination of the volcanic islands of the Pacific Ocean and Polynesia: these latter are generally of very dark colours, are of a very basic chemical nature, and characterized by the abundance of augite and olivine and the absence of quartz; whereas here in Peru and Bolivia the rocks are invariably of lighter colour, generally even white, are of a much more acid or siliceous chemical nature, contain abundance of quartz, and only in some instances was olivine at all met with.

Before concluding this notice of the volcanic rocks, I may direct attention to a point connected with the crystallization of the same, and which, I believe, has not been previously noticed: I allude to the occurrence in the trachytic and trachydoleritic rocks of perfect crystals of quartz distributed in abundance throughout the solid and compact rock-mass. In many instances, as, for example (as before mentioned), in the northern part of the Desert of Atacama, the greater part, if not the whole, of the quartz contained in the trachytic beds is so crystallized, and may easily be detached from the matrix as small six-sided prisms, terminated at both ends by pyramids, and beautifully smooth and lustrous. This could not have occurred unless the crystals had been formed whilst the rock was in a perfectly liquid state, and before the other mineral constituents had commenced solidifying.

This seems to point out one great distinction between volcanic and plutonic rocks. In the former case the quartz has been the first mineral element to crystallize from the liquid lava, as might naturally be expected from the much higher temperature requisite for its fusion. In the plutonic rocks (granite), however, the reverse is the case; the quartz has been the last element to assume the solid state and crystallize, and is not found in true crystals, except where the occurrence of drusic cavities or cracks in the solidifying rock have accidentally occurred—and even then we only find the one end of the crystal terminated by planes,—whilst at the same time the easily fusible felspar has invariably crystallized before it. It is evident that in these rocks the quartz has remained fluid or viscid at a temperature much below its point of fusion, as it occupies the spaces or intervals of the network formed by the crystallization of the other constituent minerals of the rock, which are infinitely more fusible than the quartz itself.

5. *Dioritic Rocks.*—In geological age, the next rocks which we come to are the diorites, seen in Sections Nos. 1 & 2, and which may be termed Post-oolitic, from their cutting through the strata here representing the Upper Oolitic series.

They are composed exclusively of a white felspar, together with a more or less dark-green hornblende; the rock itself is generally coarsely crystallized, but occasionally becomes so fine-grained in texture as to admit of its being termed a greenstone.

This rock is the same as that which occurs in Chile, and which has been described by Darwin in his 'Report on the Geology of South America,' under the name of "Andesite." I have preferred the name "Diorite" until chemical examination may prove it to be distinct; as in external appearances it cannot be distinguished from the ordinary diorites of Europe and other parts of the world.

Quartz is never found in this rock when normal; but at one or two places, as, for example, Cerro de las Esmeraldas and Comanche, where this rock breaks through the red sandstone beds, the diorite near to the point of contact occasionally contains some little quartz grains, which it evidently has absorbed from the rock through which it has broken; in such cases a specimen might be obtained which is mineralogically, but not geologically, a syenite.

The felspathic constituent is generally of a pure white colour, and triclinic in crystallization; but, as anorthite, albite, andesine, labradorite, and oligoclase also pertain to the triclinic felspars, it will require a chemical examination to determine its nature satisfactorily.

These dioritic rocks show themselves as a series of more or less detached or isolated patches of rock, protruding themselves through strata of various ages older than the Cretaceous period, which last-mentioned system appears to be of still later geological age.

On the Pacific, or western side of the high Andes, from Peru to Puerto Montt in Southern Chile, a distance of some forty degrees of latitude, we find at intervals such diorites breaking through the other rocks; and lines drawn through the points at which they make their appearance show that there are two parallel systems of eruption running not far from north and south, and probably at a distance of about 100 miles from one another.

In the part of South America forming the subject of the present memoir, the most western of these lines commences from a little to the east of Paposo, in the Desert of Atacama, passes through the metalliferous district of El Cobre, runs along the cliffs at Cobija, and touches the coast at Gatica a few leagues to the north of Cobija; then passing through Tocopilla, Algodon Bay, and the Ansuelo Rocks near Iquique, again enters the mainland, and, after showing itself at several points before coming to Arica, is seen in Section No. 2 at Chuntacollo and Guanuni, and still further north in Section No. 1, between Tarocache and Tarata; and, from what I can learn, it shows itself still further north in Peru, and appears to run right through South America.

The eastern line of eruption, after breaking through the Lias-rocks between La Encantada and Sandon in the Desert of Atacama, shows itself at several points before coming to Tilopozo, from which place I have specimens brought me by Dr. Philippi; entering the central part of Bolivia, unexplored as yet by any geologist, it shows itself at the Cerro de las Esmeraldas south of Corocoro, and the Hill of Comanche to the north of that place; and, from a specimen sent me, it must appear in the neighbourhood of Tio Guanaco, at the southern extremity of the Lake of Titicaca, beyond which I have at present no data for following it further north.

The eruption of these diorites appears to have been generally accompanied by the evolution of much acid vapours, probably sulphurous, to judge from the effects produced on the rocks in immediate contact with the diorites; as, wherever they break through sedimentary strata, these latter are much changed in appearance and chemical composition.

Thus we find the Lias-shales and porphyritic clay and mudstones converted into a pure white matter resembling china-clay, by the abstraction of the lime previously contained in them; and when this change has proceeded a step further, and, besides, the lime has also removed much of the alumina present, we find these rocks converted into siliceous or hornstone-like compounds, which have by several observers been regarded as rocks entirely distinct from those from which they have originally been derived: thus the quartz-porphyries of M. Domeyko and M. Pissis are of this latter character;

and the Tofos mapped on M. Domeyko's geological map of Chile in the 'Annales des Mines'* pertain to the former. Both of these classes can be seen at many points in the district here treated of, and will be subsequently noticed.

This rock is occasionally itself metalliferous, as at El Cobre in the Desert of Atacama, where the diorite is very strongly impregnated with sulphurets of iron and copper. We always find, however, that the fissures or faults formed in the neighbouring strata by the protrusion of the diorite are converted into metallic veins by the injection of metallic compounds of sulphur and arsenic; and a very careful examination has shown that the metallic veins of the Oolitic and Porphyry series of Chile, Peru, and Bolivia, which constitute the great source of mineral wealth of these countries, are all due to the appearance of this rock. The silver-mines of Huantajaya and the copper-mines of Paposo, El Cobre, Cobija, Gatica, Tocopilla, La Portada, and the veins of iron- and auriferous pyrites frequently met with, are all of this origin.

In these mineral veins I have found the following metallic compounds to occur:—

Native Gold.	Silver-glance.
,, Silver.	Galena.
,, Antimony.	Zinc-blende.
,, Bismuth.	Copper-glance.
,, Arsenic.	Copper-pyrites.
,, Copper.	Erubescite.
Arquerite.	Cuproplumbite.
Amalgam.	Stromeyerite.
Bismuthic Silver.	Iron-pyrites.
Magnetite.	Marcasite.
Specular Oxide of Iron.	Covelline.
Domeykite.	Molybdenite.
Darwinite.	Mispickel.
Algodonite.	Danaite.
Discrasite.	Glaucodot.
Copper-nickel.	Pyrargyrite.
Cobaltine.	Proustite.
Realgar.	Enargite.
Stibnite.	Tennantite.
Sulphuret of Bismuth.	

And further, from the oxidation of the above minerals, the action of the carbonic acid in the atmosphere, and the elements in the salts contained in the sea (under which this country has been submerged since the appearance of these veins), we also find the following minerals subsequently produced:—

Malachite.	Condurrite.
Azure Copper.	Silicate of Copper.
Atacamite.	,, of Copper and Manganese.
Sulphate of Copper.	Oxide of Copper.
,, of Iron.	Chloride of Silver.
Iron-alum.	Chlorobromide of Silver.
Manganese-alum.	Bromide of Silver.
Botryogen.	Iodide of Silver.

* Quatrième série, vol. ix. 1846.

A little to the north of Cobija, where, from the configuration of the coast, the line of dioritic eruptions previously described runs into the sea, we find these forming small pointed or rugged rocks jutting up from the sea, as has been noticed and figured by Von Bibra* and D'Orbigny†.

M. d'Orbigny even supposes these form part of the rock "la plus ancienne de l'ensemble," and as pre-existent to the upheaval of the Cordilleras. A careful examination, however, proved to me that they are only, as before stated, a part of the general line of diorites, and consequently younger than the Oolitic series which at these very places they penetrate into and alter as before described.

The diorites on Section No. 2, at Chuntacollo and Guanuni, are classed and coloured by M. d'Orbigny as granite, thus confounding under one head rocks which, beyond their common igneous origin, are neither in external appearance, mineral character, chemical composition, nor geological age in any way allied. As far as my researches have gone, I have not met with any granite in South America which can be proved to be of later geological age than the Devonian period.

6. *Upper Oolitic Series with interstratified Porphyritic Rocks.*—The sedimentary beds which here represent the Upper Oolitic system are so interstratified with beds of eruptive porphyries, porphyritic tuffs, and porphyry-conglomerates evidently contemporaneous, that it is quite impossible to draw any line of demarcation between these rocks; and therefore I have followed the arrangement of Darwin in Chile, in placing all the analogous rocks of Peru and Bolivia under one head. Besides the above-mentioned porphyry-tuffs, conglomerates, and interstratified porphyries, we meet with claystones, mudstones, argillaceous shales and limestones, and other beds, many of which bear a striking resemblance to the rocks of similar age in Europe. In the south of the district here treated of, we find these rocks abundantly fossiliferous; and the fossil shells from the beds of the Desert of Atacama have yielded to the researches of MM. Bayle and Coquand‡, and Dr. Philippi, about thirty-three species of recognized Oolitic forms. My collection from the same regions contains a number not yet examined, and probably will yield further species. In the part further north the country has been almost entirely unexplored, and the fossils obtained by me as yet have only been *Lithotrochus Andii*, *Ammonites Domeykii*, *A. pustilifer*, Oolitic *Posidoniæ*, a *Gryphæa*, and the cast of a *Trigonia*, as well as some vegetable remains§.

These beds are continuous from Chile right through the Desert of Atacama; and, in combination with the fossil evidence, there can be

* "Die Algodon Bay in Bolivien," Denkschriften der k. Akad. der Wissenschaft. Wien. Math.-Nat. Cl. vol. iv. 1852.

† Voyage dans l'Amérique Méridionale: Géologie, p. 97.

‡ Mém. Soc. Géol. France, deux. sér. vol. iv. part. 1[e], 1851.

§ I have not here considered it necessary to go into details as to the fossils, both as my own collection from the Desert of Atacama has not yet arrived, and because most of these more properly belong to Chile, and will be considered in my next communication when treating of that country.

no doubt as to the extensive development of this formation, which, throughout its whole extent, is strikingly uniform in all other characters.

The thickness of these beds is very considerable; but it would be too hazardous to venture any estimate of its magnitude without more decided data than are at present at my disposal. The area occupied by these rocks, as seen in the accompanying Map, is likewise very great; and we find that nearly the whole of the coast-line is formed exclusively of the above-mentioned rocks, which here form the "Cordilleras de la Costa," whilst in Chile they constitute the back range, or "Cordillera de los Andes," a nomenclature which has caused some confusion, and has been the main cause of the inaccuracy with which the mountain-chains of this part of South America has been delineated by geographers.

If we except the small strip of land at Mexillones and the included dioritic eruptions, we find that the whole coast-line of Bolivia, and as far north as Arica in Peru, is formed of these rocks. At Cobija, in Section No. 3, the Upper Oolitic beds and porphyries strike about N. 20° W. (magnetic), and dip at an angle of 30° eastward, from having been tilted up by the dioritic eruption seen in the section, which has rendered metalliferous, and also considerably altered the nature of, the rocks themselves near to the point of contact. I noticed a vein here containing grey and yellow copper-pyrites, with a little atacamite, carbonate of copper, &c., showing itself on surface, bearing N. 60° E., with a dip of 12° S.E., and cutting through both the dioritic and porphyritic rocks and shales; the latter were bleached, and at several points converted into "Tofo," or a species of clay sometimes of a pure white colour. These clays, as previously noticed, have evidently been produced by the action of acid gases accompanying the dioritic eruptions on the felspathic base of the porphyry-tuffs, &c., and which, by removing the lime and iron contained in the same, leave behind a more or less pure silicate of alumina, in the form of a white clay, or "Tofo," as such are here termed; at the same time the volatilization of compounds of iron has coloured the surrounding rocks with various shades of yellow, red, and brown.

High up the sides of the mountains in this section, a copper-mine, called the Manto de Ossa, is being worked on a considerable scale; and in this mine the ore does not occur as a vein or lode, but as a regular bed, in amongst the other strata. The cupriferous stratum itself has evidently been originally a bed of porphyry-conglomerate, or breccia, in which the interstices between the pebbles, or, rather, fragments composing the bed, have been filled up with metallic sulphurets, most probably infiltrated or injected from some neighbouring vein.

Further north, at Gatica and Tocopilla, numerous veins of copper are worked in these rocks; and at the former place they appeared to have a general run of about north-east. The Mina del Toldo, which I examined, showed for many miles a constant strike of N. 80° E., dipping about 85° to the west. The metallic compounds in these mines were native copper, atacamite, malachite, silicate of copper, black and red oxides of copper, purple and yellow pyrites, covelline, sulphate of copper, &c. These minerals frequently contained native gold in specks disseminated through them, but were stated to be unusually poor in silver.

The metallic veins which occur near La Portada, in Section No. 2, and above Tarata, Section No. 2, present features in every way similar to the above described.

In Section No. 2 is seen probably the best illustration of the arrangement and extent of the strata composing this formation. From this it will be seen that, after passing over a series of very highly inclined and thin-bedded Liassic shales dipping to the westward, we meet with the dioritic rocks of Chuntacollo and Guanuni breaking through them and altering them at the point of contact. Above these the same shales, bearing north and south with a dip of 30° to westward, are again met with, and continue, with occasional interstratification of porphyries, claystones, and porphyry-conglomerates, through Palca, Los Troncos, El Ingenio, Quebrada de la Angostura, up to Questa Blanca, where they have a north or south strike, and dip 50° to westward; here they have some beds of white trachytic tuff superposed upon them, as previously mentioned; and near this place we find an anticlinal, causing them now to dip to the eastward, which dip they retain up to the summit of the nearly 15,000-feet high Pass of Huaylillos. Shortly after passing Questa Blanca these rocks are very much altered, become flinty and siliceous, and continue so for a considerable distance, bearing N.N.W., with a dip of 50° east: in these rocks several old workings are seen on some strings of copper. The strike of the beds was at these mines found to be still N.N.W., with a dip of 20° eastward. The change in mineral nature here noticed is evidently due, as explained in a former section of this memoir, to the vicinity of dioritic rocks, and consequent metamorphic action produced by the intrusion, which also has developed the copper-veins before mentioned, and those near La Portada. The diorite is, as seen in the section, visible at one spot, and probably is much more extensive than would appear from the small eruption crossed in the line of section. From La Portada to the summit of Huaylillos the rocks are nearly all porphyritic conglomerates, frequently much altered and siliceous; and on the slope to the Rio de Azufre several beds of true interstratified porphyries are seen before coming to the great volcanic ridge of Chipicani.

Crossing these volcanic rocks, we next meet the strata pertaining to this formation at the River Caño, where they present themselves as beds of purple porphyry-conglomerate, dipping to the westward, and broken through by the lateral fissures or dykes of trachyte seen in the section both here and further eastward, at the Rio Mauri, at which place they cover unconformably the porphyry-conglomerates, as seen on both sides of the steep ravine through which this river passes. The beds here were thick porphyry-conglomerates of a purple colour and composed of smaller pebbles of porphyry overlying beds of porphyry and porphyry-tuffs, which in turn are succeeded by a second series of thick porphyry-conglomerates of the same character as the former ones. In the beds of porphyry-tuff I noticed fissures filled with a crystalline zeolitic mineral, probably stilbite *.

These porphyry-conglomerate beds continue up to the valley of Pailumani, where they are cut through by the great volcanic mass of felspathic lava seen in the section; and no trace was then found of them before coming to the eastern slope of the Pass of Chulluncayani, where we again meet with a series of porphyries which appear to belong to this series, and on the top of which I found several patches of altered red sandstone near Condorana, which evidently belonged to the Permian or Triassic series further to the east, and appear to have been carried up by the eruption of these porphyries.

In Section No. 1 another transverse view of the stratification of this series is obtained, which, however, is not so extensive as the one just described, owing to the protrusion of the great mass of volcanic matter to the eastward. The rocks met with in this section are precisely similar in mineral character to those met with and described in the former Section (No. 2), being composed of argillaceous shales, porphyry-tuffs, conglomerates, claystones, mudstones, and interstratified porphyries, cut through by dioritic and volcanic rocks, and at the western extremity of the section dislocated by a series of faults, which are easily observed on the nearly perpendicular sides of the great ravine which forms a passage through this chain from Quilla to the plains of Sama. They are seen to great advantage, and were easily sketched and followed out, from the occurrence of several bands or beds of different colours and consistency, amongst which several thick beds of coarse porphyry-conglomerate were very characteristic. This section itself will, it is believed, not require further description, as the general relations of the strata are not very complicated.

At the Morro de Arica, a hill situated to the immediate south of the town of Arica, and rising perpendicularly from the sea to a height of about 500 feet above the water's level, we also find a series of porphyries interstratified with sedimentary beds, but the age of which has not been as yet satisfactorily determined.

These beds are coloured by M. D'Orbigny as Carboniferous, from his having found fragments of *Productus* in limestone boulders enclosed in the porphyry of this hill. I have not considered it advisable at present, before more data are obtained, to separate them from the other strata with which they appear continuous, and which have yielded Liassic remains; but I admit that it requires more careful examination. A sketch-section of this hill, taken by me on my first visit to Arica in 1857, shows the following features.

Commencing from below upwards, we find at the base a series of much-burnt and altered shales, thin-bedded, and of a brown colour, but too much altered to admit of any recognition. Above this is a

* On examination, its specific gravity was found to be 2·14, the percentage of water contained in it 17·62, and its hardness 3·25; before the blowpipe it intumesces, becomes milk-white, and ultimately fuses into a white enamel.

mass of some hundred feet of intruded augitic porphyry, very characteristic, and different from all the other porphyries met with in these parts, from its containing black augitic crystals along with crystals of white felspar, in a brown, black, or grey felspathic base. Above these are seen shales similar to those at the base, of a red colour, and as if calcined*; these are succeeded by a black porphyry, on which rest altered shales, in the midst of which a thin bed of grey limestone is seen, with very indistinct traces of organic remains; above this a red porphyry, with white felspar-crystals and black specks of augite, succeeded by a second series of shales, with an intercalated bed of limestone similar to the first; above these shales a second red porphyry, then a third bed of shales, and, lastly, great beds of red porphyry and some pebbly porphyry-conglomerates, which contain agates and nodules of calc-spar, the latter frequently covered by a coating of a green mineral. I do not at present venture to pronounce any definite opinion on the true position and age of these beds, but only think that the evidence of their being Carboniferous is not sufficiently strong to be conclusive, especially when it is considered that we have no strata of that age anywhere developed along the coast of the Pacific.

Before concluding these remarks on the porphyries, I may also notice the occurrence of eruptive porphyries and some stratified porphyry-tuffs in the midst of the Silurian formation further inland. These are seen to the north breaking through the ridge which separates the valley of Illabaya from that of Sorata, a ridge which is in itself so sharp and steep as to make it appear very surprising to find it broken through by erupted porphyry, which has left the top of the ridge as a peak of somewhat hardened clay-slate: the porphyry is of a red colour, with white crystals of felspar.

Similar eruptions of porphyry occur near Oruro, breaking through the Silurian rocks. The latter are eminently stanniferous, from which circumstance, at the point of contact of the porphyry with the Silurian slates at one locality, the tin-ore or oxide of tin was found fused (M. Kroeber informs me) by the heat of the porphyry to a true white-tin enamel, such as is commonly made artificially.

In the Cerro de Potosi, celebrated for the richness of its silver-mines, and situated still further to the south, such porphyries are again found developed; and further south of this probably they run into the porphyries of the Desert of Atacama, which are, as before mentioned, contemporaneous with the Upper Oolitic beds (these eminently fossiliferous).

Drawing a line through these three points, which are coloured on the accompanying Map (Pl. I.), we find they are in one and the same direction, and have a general bearing of nearly north-west and south-east.

7. *Permian or Triassic Formation.*—The rocks now about to be treated of and considered as representing in Bolivia either the Permian or Triassic formation of Europe, are seen cut through in their

* On the top of these is a bed of saline and recent accumulation, often very calcareous, and about from 1 to 2 feet in thickness.

entire thickness in Sections Nos. 1 and 2, in which, although at first sight they seem of much greater magnitude, they do not in reality appear anywhere to attain a maximum thickness of more than 6000 feet, and generally are found to be much under this estimate. This is due to the great number of folds doubling up the beds, and also, as seen in Section No. 2 (from Santiago to Nasacara), to a series of faults which repeatedly bring up the same beds to the surface.

D'Orbigny has in his section across the same line of country coloured the greater part of these beds as of Devonian age: at Corocoro he makes a part of them Carboniferous, and at the Disaguadero (Nasacara) puts in a little strip of Triassic. As he cites no fossil evidence for these divisions, and in fact admits that he has no fossils whatever from any part of this section, this cutting up into formations beds conformable to one another, and strikingly analogous in mineral composition, seems unexplainable except by imagining that here, as generally throughout his 'Geology of Bolivia,' he proceeds with the supposition that no link in the chain of geological formations should be deficient.

The strata so classed under these different denominations can in some instances be shown to be part of one and the same series of beds, and, taken as a whole, possess all main features in common.

I have therefore not considered myself justified in retaining these subdivisions, until at least more evidence is produced, and for the present have grouped the whole of these beds as one series, under the name of Permian or Triassic. The balance of evidence appears in favour of the Permian epoch, although at the same time I admit that the absence of satisfactory fossil-evidence still leaves the question an open one for inquiry.

These beds are penetrated, upheaved, and altered by the linear eruption of dioritic rocks which runs through the whole extent of Peru, Bolivia, and Chile, and which are contemporaneous with the Cretaceous period. The section from Pisaca to Comanche shows an example of this. That they are more ancient than the Upper Oolitic series, is shown by their having been broken up and elevated by the porphyries which are found imbedded or interstratified in this system, and are inseparably connected with the same in geological age. At Condorana (Section No. 2) this will be seen to be the case. Still further north, between Condorana and Pisacoma, these beds appear to dip beneath the whole Oolitic series; but the nature of the ground was not favourable to a perfectly conclusive examination.

Fossil plants are everywhere found in this formation; but generally they are very indistinct. In some places, as at Pontezuelo, large trunks of trees silicified are found in abundance; and several specimens of carbonized wood which I procured from the sandstones of Corocoro are as yet not examined *.

* Since the above was written, sections have been made of two of these woods, and prove them to be Coniferous; but the structure is too indistinct to allow of further recognition.

I was informed that a complete Saurian head had been extracted from the same beds by M. Ramon Due, but was not successful in obtaining it, nor some fossil bones and teeth now in the museum of Avignon, in France, sent there by M. Granier, of La Paz.

These beds are superposed quite unconformably on the Devonian strata at Coniri (Section No. 2), where the red conglomerates, considered as the lowest beds of the series, abut against the nearly vertical Devonian shales.

The mineralogical characters of this system so strikingly remind one of the descriptions of the Permian rocks of Russia by Murchison, Keyserling, and De Verneuil, that when reading it subsequently to my arrival in England, it seemed as if treating of these very strata.

They consist of red, greenish, and variegated marls, saliferous and gypseous marls, gypsum beds, along with fine red sandstones, thin grey pebbly conglomerates, and red conglomerates. The marls are particularly well developed from Santiago to Nasacara (Section No. 2): at Laguna del Toro (Section No. 2) and at Corocoro (fig. 2, p. 41), we have brownish-red sandstones, with indistinct vegetable impressions, capped by thin gypsum beds and variegated marls. The gypsum beds are frequently of great thickness and extent: in some places, as at Berenguela, they are quarried to some extent, and produce abundance of fine alabaster, extensively used for the purposes of architecture (for example, the fountain in the Alameda of La Paz, &c.): some of the slabs of this material are so transparent, that tablets of it, until very lately, have been in general use in this part of Bolivia as a substitute for window-glass: I noticed that the windows of the church at Pisacoma were formed of this material in slabs of about two inches thick. The sandstones vary from red to brown in colour, and generally are not very compact, much resembling occasionally the sandstones of this formation in England, as at Pacheta (Section No. 2) we find them lighter in colour, and sometimes yellowish. The conglomerates, when intercalated with the sandstones, are generally of very insignificant thickness, often not many inches across, and contain principally small rounded quartz-pebbles, of the size of a nut, as at La Guardia (Section No. 1); those at Coniri are of considerable thickness (probably some hundred feet), and are of a deep red colour, and consist exclusively of rounded fragments of quartzites, grauwackes, clay-slates, and granite, all similar to those found in the eastern division of the diluvial formation before described, and evidently of the same origin.

As in the European Permians, brine-springs are very common in this formation; and the cupriferous sandstones, here so well developed at Corocoro, Pisaca, San Bartolo, Santa Barbara, &c., appear as the representatives of the similar cupriferous beds of Russia, the Thüringerwald and the Harz; and a further curious coincidence may be found in the determination by Mr. Kroeber of the presence of the rare element vanadium in the Corocoro copper-sandstones,—an occurrence long known as peculiarly characteristic of the Thuringian Kupfer-Schiefer.

As seen in the accompanying Map, this formation extends from the Lake Titicaca in Peru, southwards, nearly, if not quite, through the republic of Bolivia, and possibly runs right into the Argentine provinces to the back or eastern side of the volcanic range of the Desert of Atacama, and everywhere presents the same characteristic features. The cupriferous sandstones, for example, which are so characteristic of this formation, show themselves all along this extent. Beginning their appearance in the north (in the district of Puno), they are seen at the Pacheta (Section 2), then at Pisaca, Corocoro, Chacarilla, El Turco, Santa Barbara, San Bartolo, and even further south; and Mr. Villamil informs me that they are also visible in the district of Andalgalla, in the Argentine republic,—a distance of fully 500 miles from north to south. The breadth of country over which they are found is probably from 50 to 80 miles across; and the Sections Nos. 1 and 2 show the general character of their transverse section, exhibiting a series of longitudinal ridges, elevated to no great height above the general level of the plateau, seldom higher than from 1500 to 2500 feet above it, and formed by a series of anticlinals having a general strike of from N.10°W. to N.W. with varying dip.

A few of the more important observations of the strike and dip of the strata met with in Sections Nos. 1 and 2 are here appended:—

	Strike.	Dip.
Hill east of Santiago de Machaca. Soft red sandstones, with red and white marls	N. 10° W.	15° E.
Hill at San Andres de Machaca. Red and white marls	N. 20° W.	16° N.E.
Hill east of Nasacara. Red clay, with pebbles and compact red shales		20° N.E.
Hill further east of Nasacara. Red and purple clays...		10° N.E.
Pacheta de Antarini. Soft red sandstones and red marls	N.W.	45° N.E.
Laguna del Toro. Brown-red sandstones, with gypseous beds	N.W.	50° N.E.
Little east of Laguna del Toro. Red-brown sandstones, with cupriferous beds	N.W.	70° N.E.
Pacheta. Red-brown sandstones, with cupriferous beds	NN.W.	40° W.
Pacheta (further east). Red and yellowish sandstones	N.E.	30° S.E.
Pacheta (still further east). Red and yellowish sandstones		20° S.E.
Ditto. ditto		10° SE.
Ditto. ditto		30° S.E.
Ditto. ditto	N.E.	20° NN.E.
West of Tambillos. Light reddish-brown sandstones, with finely contorted lamellar structure, and the stratification marked by rows of peculiar black spots	NN.W.	25° N.E.
El Tambillo. Red sandstones	N.W.	45° N.E.
Between El Tambillo and Coniri. Red conglomerate, large pebbles of quartzite, grauwacke, and granite, occasionally a fragment of clay-slate	N.W.	40° N.E.
La Guardia (Section No. 1). Red sandstone and grey pebbly conglomerate, with colourless quartz pebbles	NN.W.	45° S.W.
East of Pisacoma. Thin fine red grey and white sandstones and pebbly conglomerates	N. 10° W.	20° S.E.

In the accompanying Map (Pl. I.) it will be seen that at Peñas, near the south end of the Lake of Titicaca, a small patch is coloured as Permian, quite detached from the rest of this formation, with which it has been grouped merely from its general resemblance in mineral character. It rises in the midst of the eastern plateau or "Puna" (as it is generally termed by the natives) as a steep ridge, broken in the centre so as to form a steep anticlinal, with the strata dipping respectively to west and eastward. The centre of this anticlinal is formed of red sandstones with gypseous seams; at Peñas the gypsum frequently occurs in crystalline plates of great purity; above these, to the westward, are some beds of coarse red conglomerate, which, in turn, are succeeded and covered by a second series of red sandstones. At Peñas the gypseous sandstones which form the anticlinal have a strike of N. 20° E., and, after dipping at a high angle to the east, gradually become less inclined, and rise, with a reverse or westerly dip, in a little hill to the eastward, thus forming a shallow intermediate basin; the red conglomerates which should overlie them do not come to the surface.

The well-known copper-mines of Corocoro (which, besides the supply for the home-consumption, exported from the port of Arica in one of the last years washed copper of the local value of 2,450,000 dollars) are situated in the red sandstones of this formation, and have been worked by the Indians from time immemorial. They were found in operation at the time of the Spanish conquest, and since then, up to the present date, have gradually increased in importance, notwithstanding that many of the mining and metallurgical processes are conducted in a manner more indicative of the times of the Inca dynasty than of the nineteenth century.

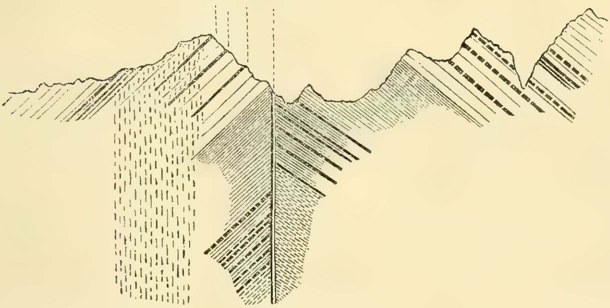
The copper occurs native as metallic grains or larger masses, disseminated irregularly in certain beds of sandstone; but combinations of copper with oxygen, arsenic, &c. are also found occurring in a similar manner to the west of the line of fault; the metallic copper, however, is the main object of exploration, and in a state of powder, resulting from the crushing and washing of the cupriferous sandstones, is exported in large quantities to Europe under the name of "copper-barilla." The want of coal or wood in this barren region prevents the other or mineralized ores of copper being worked or concentrated to a sufficiently high percentage for exportation,—the only smelting works in operation for the supply of the country, and for some little ingot-copper for exportation, being supplied with fuel from the excrements of the Llamas—it being considered that 100 quintals (each quintal = $101\frac{1}{4}$ lbs. English) of Llama dung will smelt 80 quintals of "copper-barilla*.' The furnaces employed are

* Owing to a wise provision of nature, the Llamas, when pressed by the calls of nature, do not, like the sheep, scatter their excrements over the ground at random, but resort to fixed spots, which they select themselves for the purpose, which circumstance enables an almost incredible quantity of this material (especially when we consider that in size the excrements do not materially exceed those of the sheep) to be collected for the use of the copper-smelters, and for the general supply of the inhabitants with fuel in a country otherwise destitute of combustibles. The other animals allied to the Llama (Alpaca, Vicuña, and Guanaco) also follow this laudable custom.

reverberatories with two chimneys instead of one as generally used for coal or wood.

The mode of occurrence of the cupriferous deposits of Corocoro is shown by the accompanying sketch-section (fig. 2), not drawn to a scale, but affording a pretty good general idea of the main features of this important mining-district. In this section the beds of cupriferous sandstone which are known and worked are denoted by continuous black bands, whilst those supposed to exist, but not yet proved, are shown by interrupted black bands.

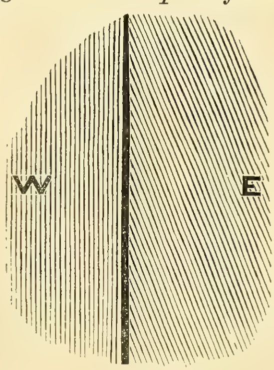
Fig. 2.—*Diagram-section of the Corocoro Copper-mines.*



1. Veta del Buen Pastor. 2. Veta de Rejo. 3. Veta Umacoia.

In the centre of the section a great fault is seen bearing nearly but not quite N.W., and dividing the whole metalliferous district into two parts; and on examination it was found to have produced both a horizontal and a vertical disturbance in the original position of the beds. Horizontally, the beds which, if merely broken and lifted up vertically on one or both sides of the fault, would naturally show parallel lines of outcrop, do not so; but on the right hand or east side of the fault they are skewed round, so as to make an angle of about 10° to the fault and the outcrop of the beds on the west side. This will be fully understood by reference to the annexed woodcut (fig. 3), which is supposed to represent a ground-plan of the present outcrop of the lines of stratification on both sides of the fault, and will not require further explanation.

Fig. 3.—*Ground-plan of the Fault.*



Still further westward, at Pontezuelo, out of reach of the immediate action of the fault, the beds were found as follows (commencing from the westward):—

N. 35° W.	Dip. 50° S.W.	Fine red sandstone beds. Found to affect the magnetic needle.
N. 35° W.	,, 45° S.W.	Coarser red sandstones, about 150 ft. thick.
N. 35° W.	,, 45° S.W.	Fine laminated and thick beds of red sandstone.
N. 40° W.	,, 45° S.W.	Fine grey sandstones.
N. 45° W.	,, 40° S.W.	Coarse grits and fine conglomerates, consisting of white quartz-pebbles, hardened grey, black, and greenish slates, and fragments of red sandstone.

Starting from the westward, over a series of fine-grained red sandstones, we come upon some coarser and more gritty strata, in which are imbedded several seams containing copper, visible on the surface by the green colour acquired by oxidation (they are not worked, being considered too poor); pebbly conglomerates are then passed over, some of which are also impregnated with copper; and we then arrive at the Veta de Buen Pastor, a fine-grained sandstone, impregnated not only with copper, but also with native silver, disseminated in fine metallic grains through the mass of sandstone. As the silver is of more value than the copper associated with it, this bed is worked exclusively as an argentiferous exploration. The succeeding strata are still coarse grits and fine conglomerates; and we come upon the Veta de Rejo, or Veta Copacabana, which also differs essentially from all the others from being rich in copper in a mineralized state of combination with arsenic, sulphur, &c. The ore from this mine being very dark in colour, from the presence of much arseniate of copper, this stratum is frequently termed the "Veta Negra," or black vein. Still lower in the same class of beds, the Veta Remacoia, or main seam of copper, is encountered and found to produce native copper, disseminated irregularly through a coarse grit, in grains, irregular lumps, or plates, sometimes of very considerable size. This seam is considered to have been the most anciently worked deposit of Corocoro, as it had been extensively worked by the Indians before the Spanish conquest; at present it is regarded as nearly exhausted, notwithstanding its extent of several miles, over which it has been explored. It is probable that by "exhaustion" is only meant a miner's mode of expressing that the depth of the workings and difficulty of keeping them free from water does not equal the value of the produce.

Below this metallic bed we find some gritty strata, and then have a characteristic bed of fine-grained crumbly red sandstone of immense thickness, the upper edge of which is seen on the surface close to the line of fault. Nothing is now known of the strata, metallic or otherwise, which may exist in depth on this (western) side of the fault; but the metallic beds depicted in the section are supposed by me to exist, for reasons which will subsequently be explained.

Crossing now over to the east side of the line of fault, we find an immense development of the same fine-grained sandstones as those noticed as composing the last bed met with on the surface to the westward of the fault; and in the lower part of this bed we find developed a series of metalliferous beds differing considerably in their features from the "vetas" (or veins,—more properly, beds) previously described as seen and worked on the surface at the other side of the fault. These, from their being of much less thickness, are called by the miners "ramos," or branches; and, for the sake of clearness, only five of these are drawn in the section, whereas many more exist, as known by the mining explorations in them: for example, in the "Mina de Cimbani" there occur five principal or workable "ramos" and nine lesser ones; and possibly a still greater depth may bring others to our knowledge.

The strike of these "ramos" is tolerably constant, and only affected by purely local circumstances; but the dip was found to be higher as we approached the fault: thus, in the Mina del Pozo the following observations were taken:—

Strike N. 25° W.	Dip. 80° E.	
„ N. 20° W.	„ 75° E.	
„ N. 35° W.	„ 70° E.	(Ramo de San Jose.)
„ N. 35° W.	„ 35° E.	
„ N. 25° W.	„ 30° E.	

the angle decreasing with great rapidity as we get away from the fault, showing that a sort of bend or curve had taken place in the beds on settling down or coming to rest after the dislocation.

A considerable amount of gypsum is found in the form of strings or veins, also as small crystalline particles disseminated through these and the beds of red sandstones of this whole series.

These cupriferous beds are very extensively explored in Corocoro, and produce a large portion of the supply of copper derived from this district. The ore obtained from the "ramos" is very different and in a much finer state of aggregation than that from the "vetas:" this probably arises from the latter being situated in the midst of much coarser and more porous or open beds of grit and conglomerates of small pebbles. In both cases the ore is seldom continuous for any great distance, but is found scattered through the metalliferous sandstones, in irregular patches or spots of a white or greenish-white colour, full of small grains of metallic copper: the colour of these spots, forming a striking contrast with the deep red colour of the rest of the bed, affords, at first sight, a sure indication of the presence of the metal. This discoloration (for such it evidently is) seems to indicate some chemical change having taken place, apparently connected with the reduction of the copper to the metallic state, and the formation of the sulphate of lime (gypsum) in these beds.

An attentive study of this interesting formation has led me to the conclusion that this change has been caused by the evolution of sulphurous fumes, disengaged, and penetrating into the pores of the strata, at the time of the eruption of the dioritic rocks of Comanche and the Cerro de las Esmeraldas, situated respectively to the north and south of the metalliferous district of Corocoro, and the protrusion of which through these Permian beds I consider as having caused the fault itself and the accompanying dislocations of the strata.

The sandstone I suppose to have been, previously to this disturbance, calcareous, and more especially so in the cupriferous parts, in which I regard the copper as having been present in the state of oxide or carbonate associated with carbonate of lime. Sulphurous acid, by combining with the oxygen of the oxide of copper to form sulphuric acid, would reduce the copper to the metallic state, whilst at the same time the sulphuric acid thus formed, acting upon the carbonate of lime, would produce the sulphate of lime (or gypsum) invariably accompanying these deposits.

It would have much simplified our ideas as to the geological age and origin of the occurrence of copper in South America if these deposits could have been shown to have had their cupriferous contents injected into them at the time of this dioritic eruption, which, as previously has been stated, is the direct cause of all the copper-veins which I had previously met with in Peru, Chile, and Bolivia. The question deserves further investigation; but the facts in hand appear contrary to this view, and to point out the copper as originally present in these sedimentary beds, probably, not as metallic copper, but in a state of combination, and subsequently reduced to the metallic state as before explained,—in corroboration of which it may be mentioned that these dioritic rocks can be everywhere proved to have been accompanied by a great evolution of sulphurous acid and other gases, by which the rocks in immediate contact have very generally been greatly metamorphosed. The supposition that the sandstones were calcareous is only in accordance with the frequency of calcareous beds met with in the unaltered parts of this formation.

The eruption of these dioritic rocks may, however, have possibly been the cause of our finding certain beds (or rather portions of beds), to the west of the fault, containing metallic silver, and impregnated with arsenic, sulphur, &c., by which arsenides, sulphides, &c. of these metals have been formed as domeykite, condurrite, copper-glance, &c.

One of these compounds, occurring in the Veta del Buen Pastor (previously mentioned), in the form of grey metallic grains disseminated in the sandstone in a similar manner to the usual occurrence of native copper before described, was analysed by me and found to be domeykite, the analysis affording—

Copper	71·13
Silver	0·46
Arsenic	28·41
	100·00

It would appear very probable that this had been formed *in situ* by the action of arsenical vapours on the metallic copper dispersed in the bed. That such a result can be thus produced may easily be experimentally demonstrated by holding a small piece of Corocoro copper-ore over a heated crucible containing arsenic.

Only a certain portion of the beds appear to have been so affected; and the spotted portion in fig. 2, p. 41, is supposed to represent this line of arsenical and other impregnation, from which it will be seen that the Veta del Buen Pastor and Veta de Rejo are altered from the surface; but the main bed, or Veta Umacoia, is, I believe, not affected at the surface; but it is so deeper down, since we find that the native copper from the Mina Cimbani contains arsenic, as seen from an analysis which is given a little further on: and I am informed that silver has been met with in depth in the Mina de Quimse Cruz; possibly this impregnation of arsenic, silver, &c. might (or in greater depth be found to) present itself as a vein of these metals.

The metallic copper of Corocoro is not only found as small grains in the sandstones, but also in nodules, irregular lumps, and plates or sheets interposed between the beds of sandstone, occasionally assuming crystalline and beautiful dendritic forms. In the Socabon de la Paz, on the Veta Umacoia (main seam), pseudomorphic crystals of native copper are found as hexagonal prisms without terminal planes; an analysis of one of these by Mr. Kroeber is annexed:

Copper	98·605
Silica	0·015
Silver	(trace)
Iron (as lost)	1·376
Metallic matter (insoluble in NO_5 HCl)	0·004
	100·000

Some are solid; but others, when sawed through, exposed a nucleus of carbonate of lime, which would lead to the inference that these pseudomorphs had been formed by the action of a solution of copper on crystals of carbonate of lime, and by some subsequent chemical change the carbonate of copper so formed had been reduced to the metallic state.

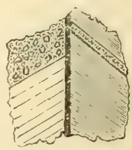
As is well known, the Permian Kupfer-Schiefer, or cupriferous bituminous shales of Thuringia, are characterized by the occurrence of the rare metal vanadium entering into their chemical composition; it appeared to me, therefore, of considerable interest to know whether this also was the case here in Corocoro, where strata occurred of very different mineral character, but supposed to represent the same geological epoch. Not having a laboratory at my command, Mr. Kroeber kindly undertook the examination; and his analysis of the washed copper-ore from the Mina de Cimbani, previously mentioned, afforded the following results:—

Water	3·500
Copper	63·341
Iron	1·200
Silver	0·003
Sulphuric acid	4·301
Sulphur	2·102
Arsenic	21·341
Carbonic acid	4·032
Vanadic acid	0·412
Sand	0·100
	100·332

from which it will be seen that even here in Bolivia, so far distant, the same chemical agencies had been in operation, and we find the metal vanadium playing a geological *rôle*, if such a simile be allowable.

As the respective names of "veta" (vein) and "ramo" (branch) denote, the metalliferous beds situated to the east of the fault had most probably, from their lesser thickness, been regarded as branches or offshoots of the former,—a supposition apparently supported by finding in the Mina Cimbani the actual contact of the former with one of the latter (Ramo de San Prudentio); and a large hand-specimen in my possession, taken from this point, and kindly given me by General Brown, the proprietor of this mine, shows, as in fig. 4, the two inclined at an angle one to another, strongly cemented together, and presenting the peculiar characters of each of these different deposits and the adjacent rocks in which they are situated. This circumstance is naturally due only to the different inclination of the strata on each side of the line of fault, causing the veta to cross the upper ramos; it is, however, interesting as showing how intimately the fault has been closed up by the grinding and sliding action which accompanied its formation.

Fig. 4.—*Sketch of the Hand-specimen, showing the Fault.*



Attempts had been, at various times, made by the miners of Corocoro to pursue their workings on these ramos through and on to the other side of the fault, and also to discover the representatives of the vetas on the eastern side of the same; but researches made without any preconceived idea of the true state of the case were not likely to be successful; and, up to the time I left Corocoro, they had not been attended with other results than pecuniary loss. Time did not permit of my making a correct section across this interesting metalliferous district, and so deciding the question; but a study of the immediate neighbourhood of the fault, and particularly the discovery to the west (and close up to the line of fault) of the upper beds of fine-grained red sandstones, very different from the coarser beds above them, and so analogous in character to those on the east side of the fault (and which also I could find developed further west), furnished me with a clue to the explication of the question as represented in the section. I have further reason to believe this to be correct from finding, much further to the west (as marked in the section), coarser and pebbly beds and traces of the outcrop of cupriferous beds, which, on examination, may possibly prove to be the representatives of the western half of the dislocated "vetas."*

Before taking leave of Corocoro, I must mention the occurrence of fossil wood in the beds of the mine of Quimse Cruz, in a carbonized state, and occasionally having the pores filled with metallic copper; also the occurrence of a fossil skeleton of a Mammal in the mine of Santa Rosa† in 1859, part of which I was enabled to obtain through General Brown, and which Prof. Huxley, having kindly examined it, pronounces to be the skeleton of a mammal of the Camel tribe, allied to the Llama, but presenting marked differences from it: it has been called by him *Macrauchenia Boliviensis*‡. See p. 73.

The occurrence of a Mammal of the post-pleistocene period in strata considered as so much older appears only to be accounted for on the supposition that the animal had fallen into a fissure in these rocks, and been subsequently covered up by the crumbling sandy débris of the adjacent rocks, which has gradually consolidated. The mine of Santa Rosa being situated close to the fault, it might be also possible that some portion of the fault itself has not been closed up, and has thus left a fissure, which might account for the depth at which these remains were found under the surface. The bones themselves are in some instances almost converted into copper, or at least the pores are filled with that metal,—a circumstance easily accounted for in strata so highly impregnated with it.

I have gone into this detailed description of the cupriferous formations of Corocoro, because they are at present the object of the most important metallic explorations in the Permian rocks of Bolivia; but from all I can learn, the other mining districts in this formation present quite analogous features, and in some cases, as at San Bartolo in the south of Bolivia, are developed on an equally large scale,—the occurrence of the metallic copper in them being exactly as described in Corocoro§.

The disturbances or convulsions which have affected the Permian

* I cannot but express here the obligations I am under to Fieldmarshal Brown, M. Pedro Saienz, and other friends at Corocoro for the kind assistance they afforded me in my researches in this part of the country.

† The former of these mines belongs to Mr. Teare, the latter to Mr. Griffiths.

‡ The occurrence of an animal allied to the only known larger mammals of this part of Bolivia (the Llama, Alpaco, Guanaco, and Vicuña) is further interesting as showing that the great Bolivian plateau, at so much earlier a period, was inhabited by animals generically allied to those found there at present, and two of which (the Llama and Alpaco) are known to be indigenous, and not to occur elsewhere in the world.

§ Mr. Abel of Copiapo has, in a letter, kindly forwarded me the following or Triassic strata in this part of the world are referable to three distinct epochs:—

1. Their upheaval by the porphyries of Oolitic age.
2. The protrusion of the still later dioritic rocks.
3. The eruptions of the volcanic rocks, properly so called.

All these have been already treated of more or less in detail; and in the sections accompanying this memoir (Pl. II.) these occurrences are in themselves sufficiently obvious to require no further explanation.

8. *Carboniferous Formation.*—The rocks of Carboniferous age met with in Bolivia, to the west of the high Andes, appear, at intervals, as small, elongated, basin-shaped deposits, the longer axis of which is more or less north-west and south-east; these basins are situated in the midst of the great western diluvial plateau, showing themselves to the north at the Lake of Titicaca, and, further south, in the provinces of Arque and Oruro.

The portion of this formation examined by me is shown in the accompanying Map (Pl. I.) and Section No. 1 (Pl. II.), where it forms the Isthmus of Copacabana in the Lake of Titicaca, the projecting headland on the other side of the Straits of Tiquina, and the islands in the lake itself. It is of very small extent when compared to the immense areas occupied by the other sedimentary formations here treated of; but it is everywhere highly fossiliferous, and presents a fauna which leaves no doubt as to its geological age: the lowest elevation of any part of it visible is about 12,500 feet; and it ascends from that height up to fully 14,000 or 15,000 feet above the level of the sea.

The unfortunate circumstance that war was declared between the republics of Peru and Bolivia when I was in this part of the country prevented me making anything but a most superficial examination. As this isthmus is divided between the two nations by such a serpentine line of frontier that in a day's journey in a straight line the traveller enters and leaves the territory of one or the other of these republics no less than seven times, and both lines of frontiers were occupied by the respective hostile armies, a geologist was placed in a very suspicious and uncomfortable position—as I had reason to experience. I was therefore glad to get over the ground as quickly

analyses of the copper-sands from San Bartolo, showing the composition of the ores found there in the cupriferous sandstone:—

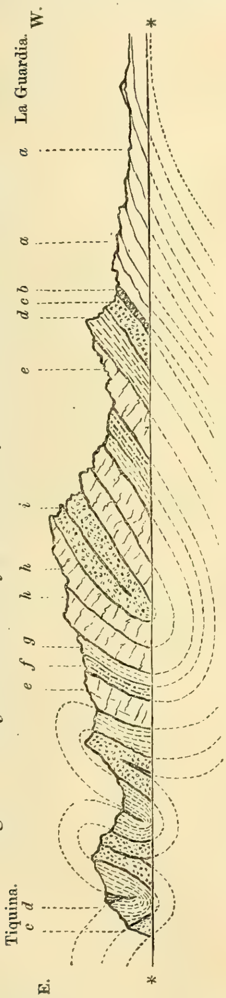
	1.	2.
Copper	57·3	34·3
Insoluble matter Silica, &c.	35·4	50·2
Alumina, Iron, &c. Soluble in acids	4·4	7·3
Carbonate of lime	1·4	6·9
	98·5	98·7

the deficiency in the above analyses being due to a portion of the copper being in a state of oxidation in the ore: thus, in No. 1, 9·9 per cent. of copper were dissolved in dilute hydrochloric acid.

as possible, and was only enabled to make observations on the immediate route; so that the section of this basin is to be regarded as a sketch merely; but, at the same time, I believe that it represents pretty accurately the real state of the case.

Starting from the eastern portion of this section, from Hachecache, after traversing the volcanic rocks and a series of highly contorted beds supposed by D'Orbigny to be of Devonian age, we arrive at the Carboniferous series, represented in the section as being unconformable to, and abutting up against, the last-mentioned beds, owing to the occurrence of a fault: this appeared to be the case; but I admit that it is not determined with as much precision as I could have wished.

Fig. 5.—*Diagram-section of the Carboniferous Basin of Lake Titicaca.*



—, Level of the Lake Titicaca.
i, White and yellow sandstones.
h, h, Thick blue limestone (Mountain-limestone).
g, Variegated shales.
f, Sandy shales.
e, e, Thick yellow and blue limestones.
d, d, White and variegated shales, sometimes calcareous.
c, c, Red sandstones (with drift-bedding).
b, Red sandy conglomerate.
a, a, White sandstones.

The strata first met with are red sandstones covered by some white sandstones, both of which alternate with and are succeeded by a rather nondescript rock, probably igneous, as the overlying beds of shales appeared to be altered as if by such agency; above these are some thin calcareous beds (fossiliferous), but the fossils I met with were too indistinct for determination; and then greenish shales, compact greenish shales, and red shales, succeeded by beds of red sandstone, forming the beach at Tiquina, at the Lake of Titicaca.

The Straits of Tiquina, which here separate the lower from the upper part of the lake, appear to the eye not to attain a breadth of more than from one-half to one English mile across, and, from the appearance of the stratification on both sides, are most probably the seat of a great fault which has broken up the continuity of the Carboniferous series.

Hitherto in the section these strata have all shown a dip to the westward, at pretty high angles, up to Tiquina: on crossing the straits, however, we meet with red sandstones, apparently identical with those on the other side, but so dislocated as to present the appearance of the broken half of an arch; and a few yards further from the beach the beds are brought to a vertical position; and thus forming a fan-shaped contortion, they commence dipping to the eastward at angles at first very high, but becoming lower and lower as we proceed westward. The relations and order of succession of these rocks are, however, much better seen in fig. 5, showing a section of the Carboniferous series, from Tiquina to La Guardia, in an east and west direction. This section appears to represent the entire thickness of this formation.

The above section will require no further explanation or description of succession; but with reference to the fossils, I may state that those which I was enabled to extract from these beds have been named by Mr. Salter as follows:—

Productus semireticulatus, *Martin.* (P. Inca, *D'Orb.*)
Productus Longispina, *Sow.* (Capacii, *D'Orb.*)
Spirifer Condor, *D'Orb.*
—— Boliviensis, *D'Orb.*
Athyris subtilita, *Hall.*
Orthis resupinata, *Sow.*?
—— Andii, *D'Orb.*
Rhynchonella (new species).
Euomphalus (Phanerotinus?).
Bellerophon; like *B. Urii*, Flem.

along with numerous fragments of Corals and Crinoids in too imperfect a state to admit of being recognized.

A *Phacops*, named in Plate IV. *Phacops Pentlandii*, was brought from Aygatchi at the south end of the Lake of Titicaca, by Mr. Pentland in 1838, and supposed by him to be in the Carboniferous rocks there; but, according to Mr. Salter, this is an Upper Devonian type. It might possibly come from the sandstone series at the base of the Carboniferous, as the rock in which the specimen is imbedded seems to point out; in such a case these sandstones may be of Upper Devonian age.

I have not had an opportunity of visiting the Carboniferous beds in the provinces of Arque or Oruro; from the former, Colonel Lloyd some time ago sent home the following species:—*Spirifer Condor*, *S. lineatus*, *Productus Cora*, *P. Inca*, *P. Boliviensis*, and *Orthis Andii*.

The Carboniferous rocks of the Department of Santa Cruz appear to form a perfectly distinct series from the above-described isolated basins, being situated at a much less elevation above the sea, and cut off from all connexion with the others by the intervening mountain-chain of the Andes. According to M. D'Orbigny they are of much greater extent; and the fossils which I have seen appear in much more perfect preservation. Mr. Cumming brought to England the following fossils, stated to be from Santa Cruz:—*Terebratula millepunctata*, *Rhynchonella Peruviana*, *R. Pleurodon*, *Spirifer Boliviensis*, and *S. Condor*.

M. D'Orbigny has coloured on his map as Carboniferous a small patch around and including the "Morro de Arica," which is seen in Section No. 2 as a steep hill rising perpendicularly from the water's edge to the height of about 500 feet above the sea. The evidence he adduces is the occurrence of traces of a *Productus* in blocks of limestone brought up by the porphyries which constitute the greater mass of this hill. This evidence does not appear to me sufficiently conclusive to warrant its being separated from the other strata, which appear continuous, and which are decidedly of Upper Oolitic age,—more particularly as we have no example of the occurrence of Carboniferous beds anywhere along the coast of the Pacific in South America. I have therefore classed them along with the Upper Oolitic series until a more careful examination, which I hope soon to make, may afford data for determining their exact position.

9. *Devonian Formation.*—The rocks which in Sections Nos. 1 and 2 are represented as of Devonian age have only been so coloured since my arrival in England: when these sections were made in Bolivia I had always regarded them as forming part of the Upper Silurian series, and coloured them accordingly.

I have been induced by Mr. Salter to look upon them as possibly Devonian, although far from being convinced of their being so in reality. The evidence of their geological age is as follows. No fossils were found in the beds of either of these sections by myself; but M. D'Orbigny cites one single specimen as occurring near Hachecache, a new species of *Orthis*, called by him *Orthis pectinata*, and regarded as decidedly Devonian by him, although Mr. Salter, judging from the figure and description of M. D'Orbigny, allows that it might pertain to any formation from Silurian to Carboniferous. The *Phacops Pentlandii*, from Aygatchi, is from near the junction of these rocks; but, as previously observed, it may possibly (as Mr. Pentland supposes) come from the base of the Carboniferous basin, the beds at the base of which might consequently be of Devonian age; but the exact locality of this fossil is too uncertain to allow it to be considered in settling this question. A series of beds of somewhat similar mineral composition occurs in the same strike as these at Oruro, in which a white sandstone contains great numbers of an *Orthis* considered by Mr. Salter as Devonian or Carboniferous from its belonging to the group of *Orthis resupinata* and *O. filiaria*. The Carboniferous series having been also developed, as previously mentioned, in Oruro, this *Orthis* might possibly belong to the sandstones at the base of the same. A *Favosites* also found near Oruro does not afford any satisfactory evidence, and we have only one fossil admitted to be truly Devonian—the *Phacops latifrons*, found in a rolled pebble in the diluvial plain near Oruro, and which is believed by Mr. Salter to agree in all essential particulars with the European and American species.

Any evidence derived from thickness of strata in a case where the Devonian, Upper Silurian, and Lower Silurian formations united, as exhibited in the sections here laid before the Society, are not considered to attain a collective thickness of more than 20,000 feet, cannot be taken as in any way conclusive against grouping the whole of these strata under the Silurian formation, when the magnitude of similar strata in other parts of the world is taken into consideration.

Having frequently heard of the immense development and thickness of quartz-rock in Bolivia before having visited that country, I afterwards paid considerable attention to this point; but in the districts traversed by me, although containing a vast area composed of more or less compact sandstones and impure siliceous beds, with interlaminated partings of blue, olive, or brownish-red shales or slates, I did not meet with any very extraordinary thickness of them.

A superficial observer, particularly if passing rapidly over the ground, might, in several places, easily be deceived into the belief that such a thickness really occurred, from finding the strata dipping to one side over a great distance, as, for example, between Hachecache and Tiquina, where the beds passed over might for this reason appear to form part of an immensely thick series. As shown in Section No. 1, these beds are in reality contorted and doubled up into an almost innumerable series of extremely sharp, small folds; and in this case I counted no less than 23 such folds in the short distance between Hancoamaya and the commencement of the Carboniferous series, owing to which the appearance of a very general dip to the eastward was presented.

In the annexed map (Pl. I.) the Devonian series is coloured together with the Silurian with one tint, from my being unable to draw so definite a line of separation as is found in M. D'Orbigny's map: their mode of occurrence is so well illustrated in Sections Nos. 1 and 2, that a description would be superfluous.

The strata themselves consist of white sandy beds more or less compact, yellowish impure sandstones and grits, and, as is seen in Section No. 1, at Hachecache, quartzite-like rocks, showing themselves both to the east and west of that place, and easily recognized in section from their rugged and shattered appearance, due to their having been too rigid to bend along with the other beds; interstratified with these are blue, olive-green, or reddish-brown shales, and beds of blue clay-slates.

Sir Roderick Murchison, some years back, in his 'Siluria,' when reviewing the Devonian formation of Bolivia as described by M. D'Orbigny, expressed himself thus:—"In the absence of sufficient proof, doubts may be entertained whether these sandstones and quartz-rocks of the Andes may be of Upper Silurian rather than of Devonian age;" and my own researches have tended to make me adopt this opinion: at the same time, however, I think it probable that there is in Bolivia a true Devonian system at the base of the Carboniferous strata, consisting of white, yellow, and brown-red sandstones, with intercalated shale-partings, which collectively do not attain any very great thickness nor occupy any very extensive superficial area*.

* These beds probably are of Upper Devonian age. I have not examined any part of the country which lies on the eastern slope of the main chain of the Andes and is coloured by M. D'Orbigny as Devonian. As will be seen from the comparative sections appended to this memoir (Pl. III.), M. Pissis does not entertain the same opinion, but in his section he represents these beds as being lower in position than the whole of the very thick strata which I am now about to describe as representing the Silurian epoch.

10. *Silurian Formation.*—The rocks which I have grouped together as pertaining to the Silurian epoch show themselves continuously, or very nearly so, over an extent from north-west to south-east of more than 700 miles; and the area occupied by them cannot be estimated at less than 80,000 to 100,000 square miles. They form the mountain-chain of the high Andes, rising to an absolute height of 25,000 feet above the sea, and, in the part of South America more particularly the subject of this memoir, continuous through Peru from the north of Cusco over the snowy ranges of Carabaya and Apollobamba, across the provinces of Munecas, Larecaja, La Paz, Yungas, Sica-Sica, Inquisivi, Ayopaya, Cochabamba, Cliza, Misque, Chayanta, Yamparez, Porco, Tomini, and Cinti, throwing off spurs along the eastern side of the main chain, right through the province of Caupolican, down to the River Beni in Mojos, into Yuracores, Valle grande, Santa Cruz and Chuquisaca, and to the east into the provinces of Oruro, Potosi, and Chichas*.

Some of the greatest rivers of the world have their sources in this mountain-chain. The Amazon, with its mighty affluents the Purus, Madera, Beni, Mamore, Rio Grande, as well as the Pilcomayo and other branches of the River Plata, are fed by the snows of this great Silurian region.

In this range also we meet with the loftiest mountains of South America, second in height only to the Himalayas. Thus we have Illampu (Sorata) 24,812 feet (25,200, Pentland), Illimani 24,155 (24,200, Pentland), Huayna Potosi 21,883, Cololo 22,374, and many others, rivalling these in height, but the elevation of whose peaks has never as yet been ascertained. These peaks do not, as M. D'Orbigny's published researches would lead us to suppose, consist of mighty cones or bosses of granite, but are in reality composed of Silurian strata,—fossiliferous, as I have proved in the case of Illampu (the highest of them all) up to its very summit†.

The Silurian series in these regions present a physical configuration, as well as other features, so unmistakeably analogous to those of their equivalents in Europe, that, notwithstanding the much grander scale on which they are developed, the geologist cannot but imagine himself breathing the air of Siluria, even before an examination of the rocks themselves confirms this suspicion.

The extensive development of clay-slate, shales, and grauwackes, along with the metallic contents of these rocks, present mineral cha-

* I have visited, of course, but a small portion of this vast territory, but have availed myself of all procurable data and many specimens of the rocks of these provinces, principally from mining adventurers and others who have explored these districts, from whom I have received much information and assistance.

† M. D'Orbigny presents us in section with the lofty Illimani as an immense cone of granite. When there, I could not find a trace of this rock; and Mr. Pentland, who ascended the side of Illimani to a much greater elevation than I did, assures me that he met with only clay-slate, and found no trace of granite or other eruptive rock. Mr. Horner has also directed my attention to the annexed paragraph in Naumann's 'Lehrbuch der Geognosie,' 2nd edit. 1858, vol. i. p. 97:—"Die beiden höchsten Gipfel der östlichen Andeskette von Bolivia, nämlich der Sorata (19,974 F.) und der Illimani (19,834 F.), bestehen aus Grauwackenschiefer, und sind keine Vulcane."

racters very similar to the Lower Silurian series in Europe, particularly as we do not, as far as I have examined, meet with the limestone beds and calcareous shales generally accompanying the Upper Silurian series. The examination made by Mr. Salter of the fossils extracted by me from these beds appears, however, to show that we probably have the whole Silurian series, from lower to upper, fully represented, notwithstanding the general uniformity in mineral character of the beds.

Starting from the north, at Tipuani, we find this auriferous region principally composed of blue clay-slates, which, from information communicated to me, I believe to cover a vast area, extending down to the River Beni. In these strata no fossils have as yet been found*; but they appear to be quite continuous with the beds which contain fossils near Sorata, about five miles south of which town I found, at a small Indian place called Cotaña, on the east side of the river, an *Orthis* (apparently *O. Aymara*), *Strophomena* (species undetermined), Annelid-tubes well defined, and small round bodies of pyrites with a hole in the centre like the joint of an Encrinite, about one-third of an inch in diameter, occurring in the blue slate†.

Still further south, on the north-west slope of Illampu, I found in loose stones, at a place called Cochipata, traces of *Cruziana Unduavi* (Pl. V. figs. 7, 8), and a little further, at Ucumarini, also on the east side of the river, Annelid-burrows and the *Cruziana Cucurbita* (Pl. V. figs. 4–6). The burrows were of varied forms and sizes, and perfect counterparts of those from Unduavi in Yungas, although this place is situated some 120 miles distant on the other side of the Andes.

Still further south I fixed my head-quarters in the Hacienda de Millepaya, and by extensive excursions from that point, and ascents as far as possible up the steep western slope of Illampu (or Sorata, as it is generally but erroneously termed‡, from the town of that name situated at its base), I was enabled to form the section of the strata represented in Section No. 1, and to examine the beds as to their fossil contents. The results of this examination are given below, premising that above the shales forming the uppermost beds repre-

* It requires an attentive search in order to discover fossils in a new country. The small number of Bolivian fossils at present known is not to be ascribed to the poverty of the rocks, but to the insignificant proportion which the few isolated spots hitherto examined bear to the vast area of this republic: as far as I have explored, this country shows evidence of being eminently fossiliferous. I believe, however, that I have, during my recent and short travels in this country, brought home more fossils than any explorer before me, notwithstanding that M. D'Orbigny and M. Pissis (who lived eight years in Bolivia) had much better opportunity than myself.

† I have to thank Mr. Salter for his great kindness in carefully examining the fossils of the Silurian, Devonian, and Carboniferous series. The names here given are those affixed by that gentleman, who has communicated a paper illustrative of the fossils which I brought home from Bolivia. See p. 62.

‡ The mountain itself is called in Bolivia by the original name of Illampu, at the foot of which, to the north, the town of Sorata is situated; and the snowy range above this town being frequently called the "Nevados de Sorata" has led to the mountain Illampu (the highest peak of this range) being called, more particularly by English writers, Sorata.

sented in this section are several beds of a quartzitic sandstone, which again are followed by the strata coloured as Devonian. The beds enumerated in the annexed table are numbered from W. to E., or in descending order, commencing with the highest:—

1. Thick blue clay-shales	No fossils found.
2. Brown micaceous slates. Strike N. 5° W. Dip 50° W.	Annelid-burrows, some globular bodies, and a fossil supposed by Mr. Salter to be a *Cruziana*; also a curious *Patella* or *Pileopsis*.
3. Blue, hard, and slightly micaceous beds	*Orthis Aymara.*
4. Less laminated micaceous beds	
5. Blue clay-shales	
6. Blackish-blue shattered clay-shales ...	
7. Thin bed, about 6 inches of slightly calcareous shales	No fossils found.
8. Shattered blue shales of great thickness	
9. Thin blue slates at Hacienda de Millepaya, much jointed	
10. Slightly micaceous blue beds	*Orthis* with fine striæ. *Orthis Aymara*, *Cruziana Cucurbita*, Annelid-burrows, and several indistinct bodies.
11. Siliceous grauwacke sandstone beds, about 100 feet thick	
12. Thin shales	
13. Grauwacke, thin bed, sandy	
14. Thin shales	
15. Grauwacke	No fossils found.
16. Thin shales	
17. Grauwacke	
18. Thin shales	
19. Grauwacke	
20. Clay-slate, dirty-blue colour	
21. Thin-bedded micaceous clay-slate	Annelid-burrows.
22. Bluish slates..................................	
23. Thin grauwacke	No fossils found.
24. Clay-slate.....................................	
25. Thick grauwacke-slates	
26. Rather hard, greyish-blue, sandy shales	*Orthis Aymara*, Worm-burrows, *Ctenodonta* (*Nucula*).
27. Clay-slates	
28. Grauwacke-slates............................	No fossils found.
29. Hardened clay-slates	
30. Whitish grey, hard grauwacke-slates, or sandy shales	*Homalonotus* (new species).
31. Grauwacke bed..............................	No fossil found.
32. Micaceous clay-slates	Annelid-burrows.
33. Blue siliceous clay-slate, or more or less sandy shale; weathering white on the surface	*Orthis Aymara*, *Phacops*, *Proetus*, *Cucullella*, *Ctenodonta* (*Nucula*), *Arca Brownii*, *Bellerophon*, *Tentaculites Saienzii*, *Raphistoma?*, *Homalonotus Linares*, Annelids, and several other fossils, indistinct. This bed seemed to abound in the above-mentioned fossils.
34. Hard, white, altered clay-slates, cut through by metallic veins...............	No fossils found.

35. Similar slates; still more altered	*Tentaculites supremus* and a Cup-coral; also several indistinct fossils, amongst which many bodies about 3 to 4 inches long, looking like *Orthoceratites*.
36. Similar strata, whitish brown or purplish	*Homalonotus Linares*, *Tentaculites supremus*, *Ctenodonta*, and a Cup-coral.

This bed is the lowest in position of the strata here examined; and, being tilted up as shown in Section No. 1, it forms the summit or knife-like ridge of this mountain which separates the barren alpine plains of the Puno, on the west, from the verdant tropical regions of the Yungas, to the eastward. On a clear day the line of bedding of the last-mentioned strata can easily be followed by the eye, up to the very highest point of the ridge itself, the steep and highly inclined sides of which prevent the perpetual snow crowning its top from showing itself as a continuous envelope, and only allowing it to lodge itself in the hollows, crevices, and offsets formed by the strata, which, as it were, prop up its summit.

The section across these beds shows also that the valley of Millepaya is merely due to erosion, and not to a fault or break in the stratification as its peculiar configuration might lead us at first to suspect; it becomes gradually narrower as it ascends, and loses itself as a ravine in the western slope of Illampu. The following observations of strike and dip were taken:—Bed No. 2: Brown micaceous slates, N. 5° W., dip 50° W. Bed No. 34: Hard, white, altered slates, N. 25° W., dip 32° W. Bed No. 35: Hardened brownish-white clay-slate, N. 10° E., dip 35° W. Other observations gave the same strike; but the dip was found respectively to be 25°, 30°, 38°, 42° W.; and still higher up in this bed the observed strike was N. 10° E., and the dip 40° W.

In these slates abundant furrows and deep grooves were observed, sometimes very deep, and running from N. 80° E. to E. & W.; also veins of spathic iron-ore, arsenical pyrites, and auriferous pyrites; veins of mispickel or sulpharsenide of iron were found running N. 50° E. to N. 60° E., and dipping to S.E. at an angle of 75°, cutting through and altering the strata.

On the sides of this mountain are also found veins of argentiferous galena, gold-bearing quartz, and metallic bismuth, the latter sometimes in large masses, occasionally faced, or incrusted on the sides, with metallic gold, sometimes in crystals. Iron-ore is also abundant*.

About ten miles to the south of Millepaya, on the west slope of Illampu, at Capara, I found, in the loose blocks of soft blue slate there, *Orthis Aymara*, a trilobite (probably *Homalonotus*), a Cup-coral, and abundant Annelid-burrows, also a Trilobite (possibly a *Calymene*) in hard grauwacke.

Still further to the south, at Umapozo, I found *Ctenodonta* (*Nucula*),

* I was informed by M. Villamil of a recent discovery of anthracite-beds in these strata; but, as yet, I have not received any satisfactory confirmation of the same.

Orthis Aymara, *Orthis* (Pl. IV. fig. 15), and *Cucullella*, all in sandy shale, and in a soft blue clay-slate, apparently the equivalent of the uppermost beds of the Millepaya section, the *Beyrichia Forbesii*, associated with an abundant small species of *Tentaculites*, which appears to me to be quite different from the *Tentaculites supremus* and *T. Saienzii* of the lower beds, both of which attain a length of occasionally more than 2 inches, whereas this small species never appeared to exceed one quarter of an inch.

Between this last-mentioned place and La Paz, I have not examined the beds for fossils, and only accidentally met with some Annelid-tubes in blue slate, about thirty miles north of that city: the position of these is uncertain.

From La Paz, to the eastward, as far as a short way below Unduavi, in the Yungas, I was enabled to make the section across the Silurian strata between these places, as shown in Section No 2. This appears to cut through the whole of this formation, from the upper beds, which before were met with at Millepaya, down to the Lower Silurian slates with *Bilobites*, a thickness of probably about 15,000 feet.

Starting to the eastward from La Paz, and crossing the great diluvial formation, with its imbedded stratum of trachytic tuff, which in the section is seen to be disturbed and dislocated by several faults, we come upon the first appearance of solid rock some miles to the east of Chuquiaguillo, and find it to consist of crumbly and much weathered clay-slate, apparently of considerable thickness, and resting upon greyish impure sandstone, which at the river of Taxani is succeeded by an alternating series of shales, slates, and grauwackes or arenaceous beds, the lowest of these being a blue clay-slate of considerable thickness*, in which an anticlinal is seen, bringing the former beds again into sight. I noticed before coming to La Lancha the occurrence of frequent frictional striæ and grooves or furrows, the bearings of several of which I found to vary from N.N.W. to N. and S., and to N.N.E. At La Lancha these slates again form an anticlinal, which from the precipitous sides of this immense ravine could be accurately delineated; further up, the clay-slates are very much contorted in the line of bedding; but towards the summit they become nearly horizontal, or rather slightly basin-shaped; and in descending, we have the dip always to the eastward until we come very close to Unduavi. To the west of the summit I did not find any fossils; but shortly after commencing the descent, the sandy shales were full of Annelid-tracks, in such abundance that rarely was a slab found that was not more or less covered with these burrows and markings. At the Mina Emma, a vein of argentiferous galena, running from 20° to 35° E. of N., and with varied but nearly vertical dip, is being worked; and there I noticed abundant elongated round bodies in the slate, which from their configuration, and from having invariably a hollow tube in the centre, appeared like *Orthoceratites*: they were composed chiefly of carbonate of iron.

* On the top of these highly inclined strata is seen a small patch of diluvial conglomerate, apparently a remnant of the formation further to the west.

The rocks from this mine to Pongo, and from that place down to Unduavi, consist entirely of more or less arenaceous shales, thin-bedded and containing frequently indistinct traces of fossil forms. As seen in the section, these slates are dislocated by three faults, which faults are filled with metallic matter, and form the veins on which are worked the mines "Delphina," "Mercedes" (60° N.E. strike, 85° E. dip), and "Pilar," producing argentiferous galena more or less antimonial, for the supply of the furnaces at San Felipe.

In M. D'Orbigny's map, the greater part of these slates are coloured as granite; and, according to him, Pongo is situated in the midst of the granite, which in his map here forms a broad band, constituting the centre of this range of the Andes. As seen in the section, no trace of granite visible to me occurs here; and, in fact, no granite whatever is crossed in the direct line of section from La Paz to as far east of Unduavi as I examined. The small outburst of granite seen at Silla Tuncari does not occur in this line; and I have purposely deviated the section from the direct line in order to show it. Granite is also met with in the Nevado of Chucura, at Yoja, and at Takesi (to the south of this section); but it does not form the continuous band seen on M. D'Orbigny's map, which appears in this, as in many other instances, to have been coloured from imagination*.

The granite of this chain of the Andes shows itself at various localities, apparently isolated one from another†, and appears to be of the same age as the auriferous granites of the rest of the world, with which it is identical in mineralogical and chemical composition, being composed of white orthoclase, colourless quartz, and black or white mica, and containing frequently spots of iron-pyrites, which sometimes, as at Silla Tuncari, stains the granite of a brown colour from oxidation. The gold in this is found in the quartz, or along with the pyrites; and it would occasionally, at least, appear that this rock is more auriferous in proportion as it contains more pyrites. As the whole of this Silurian formation is eminently auriferous, and contains everywhere frequent veins of auriferous quartz, usually associated also with iron-pyrites, a study of the occurrence of these gold-veins leads me to attribute all such veins to the proximity of granite, and to regard the veins of quartz, iron-pyrites, &c. as having been directly injected from the mass of granite itself. We know that, during the cooling and solidification of granite, the quartz

* In the map which accompanies this memoir (Pl. I.) the granite is not separately coloured, on account of its forming here a subordinate part of the Silurian district. It being difficult to get details into so small a scale, the Devonian and Silurian, along with the granite rocks which disturb them, are coloured with one tint. I must also confess that, without more data, it would be impossible to do otherwise without falling into errors similar to those of M. D'Orbigny.

† I must observe that I am not alluding to the great granitic range which occurs, according to M. Pissis, still further to the east, near Coroico. I, unfortunately, was unable to pursue my section further, from the rainy season having rendered the rivers impassable: an attempt to ford the river below Unduavi having resulted in the loss of two animals with all the baggage, made it more prudent to retrace my steps, however unwillingly, to La Paz.

present in some is the last mineral element to crystallize and become solid; it seems probable that, during this cooling, the consequent expansion due to the crystallization of the constituents has forced those components (quartz, along with iron-pyrites, gold, &c., which latter, from their very low fusibility, would remain longest of all in a fluid state), still fluid, into the fissures of the neighbouring rocks, and so formed such auriferous quartz-veins, which observation shows are only developed in the slate-rocks at no very great distance from granitic eruptions, either visible or such as, though hidden, may reasonably be inferred to exist. This granite is the same which is everywhere met with in the diluvium of the eastern plateau, as large blocks, frequently used as a building-material where solidity is required*.

Although we do not meet with any actual granite on the direct line of section without diverging (as I have done in order to show the granitic outburst of the Silla Tuncari), we find, a little to the west of Unduavi, these beds broken through by a fault, probably due to this eruption. The granite has also caused an anticlinal in the strata, which hitherto, from the summit of the pass, had constantly dipped to the east, but now become inclined to the westward, and continue so to San Felipe, near which place, however, after presenting some contortions in their bedding, they again resume their western dip, having at the Angostura, below San Felipe, a strike of about N. 30° E., with 50° westwardly dip.

At San Felipe the hard sandy shales, of a blue colour and slightly micaceous, contained frequent Annelid-tracks and -burrows, and a great number of small nail-shaped bodies like the spines of an *Echinus*, also others horn-shaped, with concentric rings, both of which Mr. Salter attributes to Annelids. Along with these were frequent specimens of the *Cruziana Unduavi* (Pl.V.fig. 7); and I also noticed several specimens of the *Boliviana bipennis* (fig. 11). Traces of other fossils were everywhere frequent, but too indistinct to permit determination.

About half a mile further down the valley, Annelid-tracks were found in abundance in the hard blue siliceous slate, as well as imprints of *Cruziana*. About one mile further down, the thin-bedded sandy and highly-indurated rocks were literally covered in all directions with Annelid-tracks and -burrows, the same nail-headed bodies previously described, and a variety of other and peculiar markings. I also found some indistinct specimens of *Boliviana Melocactus* and *Cruziana Cucurbita*, and several better ones of *Cruziana Unduavi*, which last were found a little lower down the valley. Ripple-marks are everywhere visible in these beds.

In another valley, called the "Quebrada de Aceromarka," situated a little to the south of Unduavi, in similar beds, specimens of the shapeless *Cruziana Cucurbita* were found in abundance, in company with the *Boliviana Melocactus*, and a single specimen of the *Boliviana*

* The corinthian columns of the new cathedral at La Paz are hewn out of this granite, and are most creditable to the architect, especially when it is considered that the cutting of this hard material has been entirely executed by the Aymara Indians of the district.

*proboscidea**, with numbers of other still more indistinct fossil impressions.

I have not a doubt that these beds, on careful search, would yield a rich harvest to the palæontologist; but I had not time to devote to more than a very rapid survey of the country†.

The thickness of the Silurian strata seen in this section cannot be less than 10,000 feet: opposite San Felipe a good section is seen on the nearly perpendicular face of the mountain called "Perolani," which, by measurement, is 6000 feet above the valley; and, as the strata in the centre of this mountain are nearly horizontal, the thickness of strata in that place cannot differ much from the total height of the mountain above the level of the valley; and it is not too much to add 4000 feet for the strata visible both above and below these beds.

The Silurian strata have been disturbed by the following igneous outbreaks, in succession. Commencing with the most ancient,—

1. Intrusion of the auriferous granite, along with its associated auriferous, and probably other metallic, veins: in parts it has metamorphosed very considerable areas of the Silurian beds.
2. The porphyritic eruptions of Hillabaya, Potosi, Oruro, &c.
3. Protrusion of the metalliferous diorites.
4. Still later trappean dykes, which, I am informed, occur at several localities; but I have not personally come across them in Bolivia.
5. Volcanic eruptions near the Lake of Titicaca, &c., breaking out at the borders of this formation, but which, as far as I am aware, do not anywhere disturb the main chain of the Silurian Andes of Bolivia. On inquiry, I found that this district was exempt from the earthquakes which are so prevalent and destructive both in this and the adjacent Republics.

The metallic veins‡ which occur in these Silurian strata contain the following minerals:—

Metallic Gold.	Fluor-spar.
,, Silver.	Selenide of Lead.
,, Bismuth.	,, of Cobalt and Lead?
,, Antimony.	Sulphuret of Antimony.
Oxide of Iron (magnetic).	,, of Molybdenum.
,, of Tin.	,, of Silver (Silver-glance).
Tin-enamel.	Blende.
Chloride of Silver.	Galena.
,, of Lead.	Magnetic-pyrites.

* I have to thank Mr. Kroeber, the Director of the San Felipe Mining and Smelting Company, for his hospitality, and the assistance afforded me in my search for fossils in this region.

† Mr. Kroeber informs me of some anthracite-deposits, more like fissures filled up than true beds, and, according to his description, like some in Shropshire. This, however, requires confirmation.

‡ I refer here to such veins as are not (so far as can be determined by superficial examination) in connexion with the eruption of the metalliferous diorites previously described as of Post-oolitic age.

Iron-pyrites.	Fahlerz.
Copper-pyrites.	Silver-fahlerz.
Tin-pyrites	Zinc-fahlerz.
Sulphuret of Copper and Bismuth?	Wolfram.
Jamesonite.	Calc-spar.
Plagionite.	Carbonate of Iron.
Zinkenite.	,, of Lead.
Lonchidite.	Sulphate of Lead.
Mispickel.	Phosphate of Lead.
,, (nickeliferous).	Arseniophosphate of Lead.
Danaite.	

The above enumeration is doubtless far from complete; but it is quite sufficient to show at a glance how strikingly the mineralogy of these older strata differs in its general features from that of the more recent rocks before described.

I may here notice some rocks which occur on the immediate line of the Bolivian coast, and which, for the present at least, I class along with the other metamorphic Silurian strata of this part of the world, not from being able to prove with certainty that they are of Silurian age, but because, from their position and their relations to the newer formations in contact with them, they appear to be only a continuation of the beds which in Chile form the Silurian series of the coast.

They are so very much altered by the effects of the eruptions of granite, porphyry, and diorite, which here break them up, that even their sedimentary nature can hardly be recognized except at some few localities.

To the south, in the Desert of Atacama, they appear as gneissic or metamorphic schistose rocks, broken through in all directions by granitic outbursts, the granite itself being precisely identical in external appearance and mineralogical composition with the previously described auriferous granite of Silurian age in the Eastern Andes. It is composed at Mexillones, for example, of white orthoclase, colourless quartz, and dark mica. Further southward the sands arising from the disintegration of this granite have been proved to be auriferous.

At Cobija, the black rock which forms the rugged low cliffs and detached rocks in the sea and along the shore appears also to belong to this series, although in appearance it frequently resembles a compact trappean rock or a black porphyry. On closer examination, I am disposed to consider it as a clay-slate or other argillaceous or calcareo-argillaceous rock, fused *in situ* by the action of the masses of porphyry or diorite resting immediately upon it, or of the granite which has upheaved and broken it up, and which, although not itself visible at the Port of Cobija, is seen a little further to the south. This rock varies in colour from a bluish-grey to grey or bluish-black, and, like all altered rocks of this class, contains green epidote frequently disseminated in it, or forming imbedded geodes: geodes of quartz or calcedony also occur; and when the rock appears to have been completely fused I have noticed some dark-grey felspar-like mineral in it; in texture it then much resembles a basaltic or trappean rock. It is extremely hard and tough, and is cracked, fissured, and jointed in all directions. Occasionally one set of joints presents pretty regular and parallel lines of fracture. Many small strings of copper-ores (sulphurets, carbonates, and oxychlorides) are seen cutting through them, with various bearings, from N.E. to E. and W., dipping at very high angles.

Conclusion.—In conclusion, I must direct attention to the three comparative sections of the country from Arica on the Pacific to the Yungas on the eastern side of the High Andes of Bolivia (Plate III.). Although this plate is, of course, to be regarded only as a diagram, it represents correctly a summary of the conclusions at which M. D'Orbigny*, M. Pissis†, and myself have arrived in traversing the same line of country.

On examination, it will be observed that great and unaccountable differences are here depicted; and it must be left to the reader to judge, from the perusal of the different memoirs of the three authors, how far each of them may be sound in his views.

This plate does not require any further explanation than the remarks which have been occasionally made under the heads of the different formations; but it is particularly important as showing at a glance these several discrepancies, and in its bearings on the general tenor of the results here brought forward. Subsequently it will be required for reference in the second and third parts of the memoir of which this communication is the first part, and which will treat of the Geology of Chile and the Argentine Provinces; it will then be found most essential in explaining and reconciling the various statements which have been made in reference to the geology of these countries.

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2. *On the* Fossils, *from the* High Andes, *collected by* David Forbes, Esq., F.R.S., F.G.S. By J. W. Salter, Esq., F.G.S.

[Plates IV. & V.]

I have examined this unique series with some care; and with a collection of above 200 specimens there should be no unusual difficulty in assigning the true geological date. The specimens are generally perfect enough to show the generic characters, though in very few cases is their preservation complete; and it is thought better at present (especially as Mr. Forbes intends returning over this difficult ground) to figure all the chief forms, and give specific characters only to the more prominent fossils. All the specimens from the slate-rocks are distinct from those previously published.

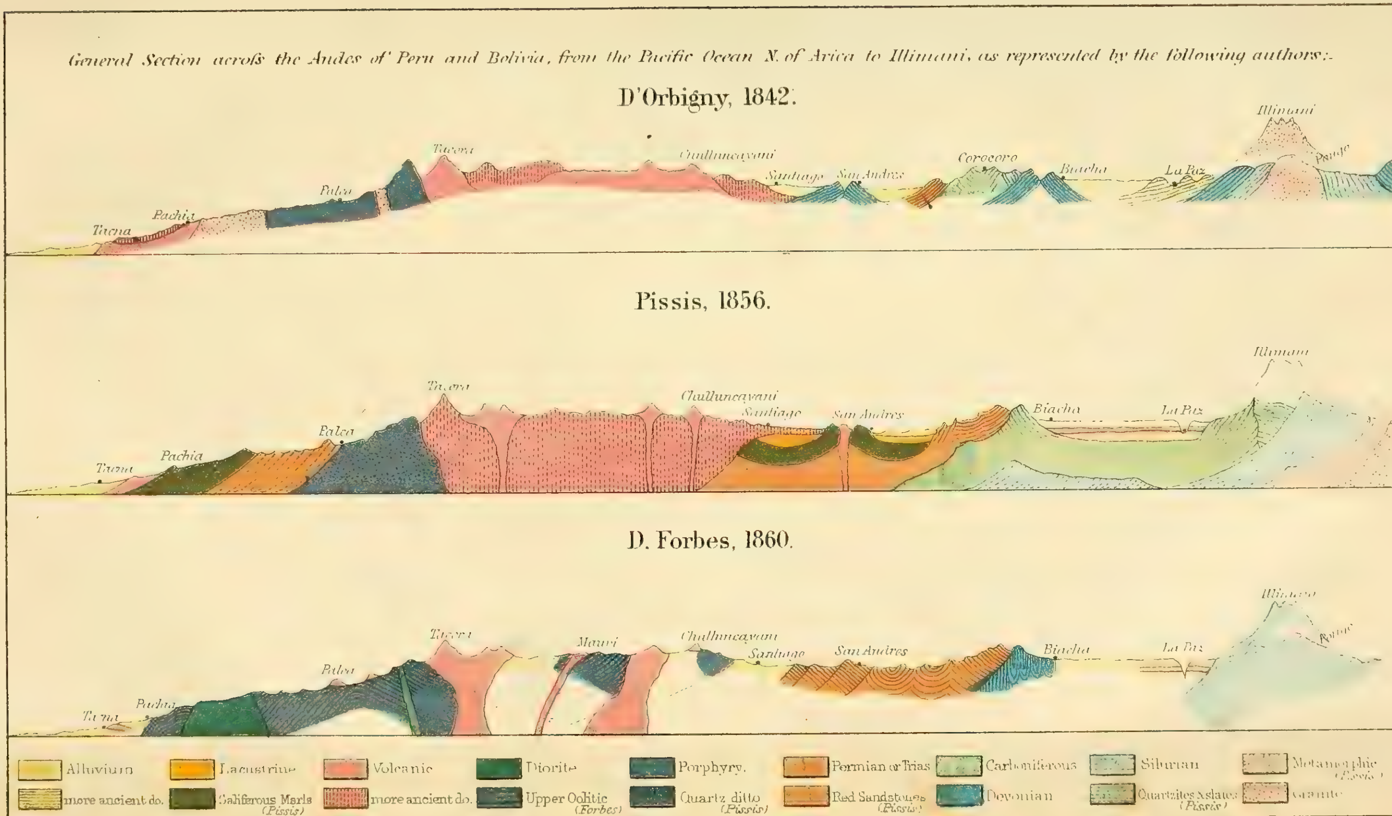
* Voyage dans l'Amérique Méridionale, tome iii., Partie Géologie. Par M. Alcide d'Orbigny. Paris, 1842.

† "Recherches sur les Systèmes de Soulèvement de l'Amérique du Sud." Par M. Pissis. Annales des Mines, 5me sér. tome ix. 1856.


GEOLOGICAL SKETCH-MAP
of part of
BOLIVIA AND PERU
By D. Forbes, F.R.S. F.G.S. &c.
Saline deposits
Oolitic
Diluvial
Permian or Triassic
Volcanic
Carboniferous
Diorite
Silurian with Devonian & Granite
PERU
BOLIVIA
ARGENTINE PROVINCES
CHILE
PACIFIC OCEAN
Lake Titicaca
Illanipu
Achacache
Yungas
La Paz
Illimani
Corocoro
Disaguadero
Cochabamba
Oruro
Rio Grande
V. Sahama
Lake of Poopó
Sucre
Potosi
Tarapacá
V. Misti
Arequipa
Puno
Sama
Yarada
Tacna
Arica
Sect. 1
Sect. 2
Pisagua
Iquique
Rio Loa
San Bartolo
V. Atacama
Tocopilla
Gatica
Cobija
Mejillones
V. Licancau
V. Toconado
El Cobre
Paposa
V. Llullayaca
W. West lith.

Sa

Sections across Peru and Bolivia, by David Forbes, Esqre. F.R.S., F.G.S., &c.
Section No. 1. From the PACIFIC OCEAN to the highest summit of the ANDES OF SOUTH AMERICA: 335 miles. General direction North 40° East.
Section No. 2. From the PACIFIC OCEAN AT ARICA TO YUNGAS IN BOLIVIA: 320 miles. General direction North-East.
Alluvial and Diluvial.
1 In general
2 Volcanic debris
3 Volcanic Porphyritic & Dioritic do.
4 Volcanic & Porphyritic do.
5 Volcanic & Permian do.
6 Volcanic & Silurian do.
7 Porphyritic & Permian do.
8 Permian do.
9 Silurian & Granite do.
Volcanic.
10 In general
11 Trachytes and Trachytic tuffs.
12 Dolerites Trachydolerites Feldspathic
13 Volcanic Breccia with tuff and debris.
Post-Oolitic.
14 Diorite (Hornblende & Felspar).
Upper Oolitic.
15 In general
16 Massive crystalline erupted Porphyries.
17 Shales, mudstones, clay-stones Porphyry tuffs & occasional thin impure limestone.
18 Compact tuffs, interstratified Porphyries, and thicker compact shales.
19 Breccia and Conglomerates, all formed of Porphyritic components
Permian.
20 In general.
21 Altered Rocks.
22 Red and yellow sandstones, marls, & clays, Gypsum-beds and Copper-sandstones.
23 Conglomerates
Carboniferous.
24 In general
25 Shales and slates.
26 Grits and sandstone.
27 Limestones.
Devonian.
28 Slates, shales, and yellow white sandstone.
Silurian.
29 In general.
30 Shales and slates.
31 Grauwacke & impure & hardened sandstones.
Granite (Middle Silurian)
32 Auriferous, composed of Orthoclase (white), Quartz (colourless) & Mica (black).
Plains of Sama
Rio Mauri
Guarina Cota
Pizacoma
Huacullani
Guardia


General Section across the Andes of Peru and Bolivia, from the Pacific Ocean N. of Arica to Illimani, as represented by the following authors:-
D'Orbigny, 1842.
Tacna
Pachia
Palca
Tacora
Chulluncayani
Santiago
San Andres
Corocoro
Biacha
La Paz
Illimani
Pissis, 1856.
Tacna
Pachia
Palca
Tacora
Chulluncayani
Santiago
San Andres
Biacha
La Paz
Illimani
D. Forbes, 1860.
Pachia
Palca
Tacora
Mauri
Chulluncayani
Santiago
San Andres
Biacha
La Paz
Alluvium
more ancient do.
Lacustrine
Califerous Marls (Pissis)
Volcanic
more ancient do.
Diorite
Upper Oolitic (Forbes)
Porphyry.
Quartz ditto (Pissis)
Permian or Trias
Red Sandstones (Pissis)
Carboniferous
Devonian
Silurian
Quartzites & slates (Pissis)

Of the Carboniferous forms little need be said. They are the same as those described long ago in D'Orbigny's large work; and similar specimens were brought home by Mr. J. Cumming during his explorations for recent shells in Bolivia. The resemblance to British fossils of this epoch is most striking, and some of the species are identical.

The Devonian gives us very scanty traces, yet scarcely doubtful. Occurring, as it does, between the Carboniferous basin and the slate-rocks, it falls naturally into the place indicated by the few fossils known to us. Mr. Pentland brought home from Aygatchi, in Bolivia, a Trilobite from this formation.

The age of the slate-rocks, however, was for a long time doubtful; and the aspect of Mr. Forbes's collection is so unlike that of any British or American type, that, while their discoverer was strongly urging their Silurian age, my own prejudice gave them a Lower Devonian character. The large *Homalonoti* (the only conspicuous Trilobites) are, on the whole, more like Devonian forms than Silurian; and the shells are of just such types as might be referred to either of these systems. The *Tentaculites* would bear the same interpretation; but a small *Beyrichia*, very rare, occurs just at the top of the whole series, and this particular form of the genus is not known in Europe to trespass beyond the Uppermost Silurian limit, or the basement-beds of the Devonian at furthest. Again, the *Bilobites* (whatever these obscure fossils may be) are all of Silurian age, and they are numerous in Mr. Forbes's collection. They have generally been regarded as Lower Silurian forms, and are, indeed, far more plentiful below the Caradoc rocks than elsewhere. But too much stress must not be laid on this; for one characteristic species occurs in the Llandovery or Clinton group of New York; moreover, all the specimens from the Andes, whether the large ones described by D'Orbigny, or the smaller ones now brought home, are of species distinct from those known in other districts. I do not believe them to be plants, but have no definite idea of their true structure, further than that they were tough hollow crusts, not soft solid masses as sea-weeds generally are.

One other remark before proceeding to notice the separate species. Wherever we meet with new areas of Silurian rocks, we find we have in them new Natural-history provinces of these old seas: it is so in India, according to Colonel Strachey's researches; and it is so in Australia: no species from either region is, I believe, identical with those of Europe. The same cannot be said of the Devonian fossils, which ranged very widely during the later part of that epoch; and the Carboniferous types are almost cosmopolitan, many of the same fossils ranging from the North Pole to Australia, and from North America and the Andes to Nepaul. It is, I think, chiefly due to this circumstance that we have been accustomed to regard the Palæozoic types as having an almost universal diffusion. This is nearly true as regards the genera, but, except in the remarkable case of the Mountain-limestone fossils, without much evidence in the case of species.

CARBONIFEROUS.

From the small basin of these rocks at the Isthmus of Copacabana, in the Lake of Titicaca, the following species were obtained:—

Productus semireticulatus, Martin. (*P. Inca*, D'Orb.) Pl. IV. fig. 1.
—— *Longispina*, Sow. (*P. Capacii*, D'Orb.) Pl. IV. fig. 2.
Spirifer Condor, D'Orb. (*Sp. striatus*, Sow. ?)
—— *Boliviensis*, D'Orb.
Orthis resupinata, Sow. ?
—— *Andii*, D'Orb. (from a Santa Cruz specimen). Pl. IV. fig. 3.
Athyris subtilita, Hall. (*Ter. Peruviana*, D'Orb.) Pl. IV. fig. 4.
Rhynchonella (a species with three raised ribs, very like some varieties of *R. Pleurodon*; also from a good Santa Cruz specimen). Pl. IV. fig. 5.
Euomphalus, with separated whorls (possibly a *Phanerotinus*).
Bellerophon, sp.; a close ally of *B. Urii*, Flem. Pl. IV. fig. 6.

Corals, also, and Crinoids, all imperfect. D'Orbigny describes a *Favosites* and a Cup-coral, a *Fenestella*, &c.; and Col. Lloyd's collection from Arque, as well as Mr. Cumming's from Santa Cruz, both include such specimens. I see no essential difference between the *Productus semireticulatus*, so common in Britain, and the so-called *P. Inca* of D'Orbigny; and I think it would puzzle any one to draw a clear distinction between his *P. Capacii* and our own familiar *P. Longispina*, found everywhere in the Carboniferous Limestone. The *Spirifer Condor* has certainly rougher ribs than the ordinary varieties of *Spirifer striatus*, and may be distinct. We figure (Pl. IV. fig. 3) one remarkable form, said to be from Santa Cruz, but, at all events, from the Carboniferous Limestone of the Andes, of which less perfect specimens occur in Mr. Forbes's collection. It is a beautiful species of the *Orthis resupinata* group, and has received the absurd name of *O. Andii* from D'Orbigny.

Our figure of the *Rhynchonella* (Pl. IV. fig. 5) is also from this collection, which was sent home by Col. Lloyd many years back.

DEVONIAN*.

ORTHIS, sp. Pl. IV. fig. 7.

Internal casts only. It belongs to the group of *Orthis resupinata* and *O. Michelini*, and thus may be either Carboniferous or Devonian.

Locality. Oruro. Sent from thence by Col. Lloyd. (Mus. Practical Geology.)

* Of the seven species considered Devonian by D'Orbigny, only four appear to be *certainly* supra-Silurian; and these four may (from their type) be either Devonian or Carboniferous. They are—*Rhynchonella Peruviana, Spirifer Boliviensis, S. Quichua*, and *Orthis Inca*. *Spirifer Quichua* is from Chuquisaca, the other three from Cochabamba.

The *Orthis pectinata*, on which D'Orbigny lays stress, seems to me to be very unsatisfactory. It is only the cast of a single valve, without hinge or teeth, of a shell destitute of any marked characteristics. I should not like to speculate as to its age; but M. D'Orbigny may have seen Devonian species like it.

Phacops latifrons, Bronn. (*P. Bufo*, Green.) Pl. IV. fig. 8.

In all essential particulars this agrees with the common Devonian species known in Europe under the name *P. latifrons*, and in America by Dr. Green's appellation *P. Bufo*. Comparing it with either Spanish or American specimens, I see no difference, except a somewhat flatter axis, and perhaps one rib fewer in the tail-piece. The group of *Phacops* to which it belongs sometimes occurs in Upper Silurian strata; but this species is nevertheless a most characteristic Devonian form, and has an immense geographical range.

Locality. Near Oruro. In a rolled pebble.

Mr. Pentland found near the town of Aygatchi, Bolivia, another *Phacops*, which, from its type, belongs most certainly to Devonian rocks. It is one of the group *Cryphæus*, distinguished by having the border of the tail spinose; moreover, it is not far removed in affinity from the characteristic *Phacops Caffer* and *P. Africanus* of the Cape of Good Hope. *P.* (*Calymene*) *Verneuilii* of D'Orbigny appears to belong to the same section, and is probably of the same age.

Phacops (Cryphæus) Pentlandii, n. sp. Pl. IV. fig. 9.

Rather more than 2 inches long, and $1\frac{1}{4}$ inch broad, convex, long-ovate, with a subtriangular head; the tail pointed, ribbed throughout, and with a tubercular or subspinose border.

Head $\frac{3}{4}$ inch long, blunt-trigonal; the glabella broad, inflated in front, the forehead-lobe rhomboidal and blunt-pointed, but not overhanging; the facial suture supra-marginal. The margin itself is thin in front, thickened only round the sunken cheeks, and is cut near its (spinose?) posterior angle by the facial suture. Eye prominent, of many moderate-sized lenses, set far forward, but not close to the glabella.

Body-rings (much broken) with the axis very prominent, and with four spines on each ring, besides one *within* the fulcrum on the pleura, and one (or two?) *outside* it; pleural groove deep, broad; ends of pleuræ truncate.

Tail-piece triangular, 6 lines in length, wider than long, with a very convex axis reaching the tip, and marked by six or seven strong rings, the rest indistinct. The sides are about the same width as the axis, with six strong curved ribs (the upper ones duplicate), not furrowing the narrow border, but faintly continued on it into marginal tubercles. Both the lateral ribs and the axis have tubercles on them. The terminal spine, if one existed, is broken off.

There are several Bohemian species of *Phacops* which resemble this in the tubercular ornaments of the body; but none that I know have a tuberculato-spinose border to the tail; and this character, combined with the inflated forehead-lobe, will certainly restrict the fossil to either Upper Silurian or Devonian: it cannot be Carboniferous.

Locality. Aygatchi (*Mr. Pentland*, 1827). It comes, according to that gentleman, from beds of the Carboniferous series; it would appear from Mr. Forbes's statements, that it could only be from the sandstones at their very base; and I must claim these as Upper Devonian.

Favosites (?), sp. Pl. IV. fig. 10.

I find no pores in any of the tubes (but only some tubercles), and very few traces of tabulæ. Possibly it is not of this genus.

Locality. Given to Mr. Forbes (by Mr. Bogen, of Tacna) as having been found near Oruro.

UPPER SILURIAN.

All the thick beds of sandstone, intercalated with many layers of sandy shale, appear to lie in the upper part, or middle part at least, of Mr. Forbes's Silurian section; and in these the chief part of his fossils were found. The lower beds (chiefly shale and thin sandstones) contain the *Bilobites* (or *Cruziana*) and very little else; and, seeing that his sections gave a measured thickness of at least 15,000 feet (all of which, as he judges by the mineral aspect, belongs to one and the same series), there is much reason for supposing the lower part to be of Lower Silurian date. This is borne out by the presence of the *Bilobites*, which, as above noted, is chiefly a Lower Silurian type.

D'Orbigny has figured a Graptolite, with one row of cells, from South America; and this alone would prove the presence of Silurian rocks, upper or lower. It is from Tacopaya, Santa Cruz.

Homalonotus Linares, n. sp. Pl. V. figs. 1 & 2.

Body (?) faintly trilobed (fig. 1 *a*); pygidium (fig. 1 *b*) $1\frac{1}{4}$ inch long, and about as broad, triangular, regularly convex, with the sides not abruptly bent down. The axis is but faintly marked, quite as broad as the sides, and scored by about sixteen rings; the sides show nearly as many furrows, none of which reach the margin. The apex is pointed, the tail gradually tapering to it, not abruptly acuminate. The sides (apparently from fig. 1 *b*) are bent inwards beneath; and the apex also shows some indications of a broadish triangular space. The whole surface appears smooth.

The species is not unlike *H. delphinocephalus*, Murch., but has many more ribs, and a longer axis.

Locality. From the highest point reached by its discoverer: he found it on the all but inaccessible face of Mount Illampu, at the height of 20,000 feet. Named in honour of his Excellency the President of Bolivia.

Homalonotus, sp. Pl. V. fig. 3.

Not perfect enough to describe. It has a blunt rounded shape, like that of *H. obtusus*, Sandberger, and several other German and French species from Devonian rocks. The axis is more strongly ribbed than the sides, and the surface is roughly granular.

Locality. From the same mountain as above, at a somewhat lower level (about 15,000 feet).

Proetus, sp. (a fragment). Such fragments are common both in Upper Silurian and Devonian rocks.

Locality. Same mountain (16,000 feet).

[Beyrichia Forbesii, Jones, n. sp. Pl. IV. fig. 13 *a, b, c,* nat. size and magnified.

Carapace-valves oblong-ovate; straight on the dorsal and obliquely curved on the ventral edge; obtusely tapering at one end, obliquely truncate at the other; bordered below and at the ends with a slight rim: surface raised into four, equidistant, unequal, transverse, rounded ridges; the one next to the narrow end of the valve lowest and shortest, the next one highest and longest of all.

This is nearly allied to *Beyrichia Bussacensis* from the Lower Silurian rocks of Portugal (Quart. Journ. Geol. Soc. vol. ix. pp. 141, 160, pl. 7. figs. 5 & 6); but it is narrower, and its ridges are differently proportioned. It also approaches in form to the figure of a *Beyrichia* that has been published (without description) by Prof E. Emmons among some Silurian Fossils of North America in his 'Manual of Geology,' 2nd edit. 1860, p. 100, fig. 90.

This little fossil is seen in some numbers (together with *Tentaculites*) on a small piece of dark-grey calcareous schist from the western slope of Illampu in the Bolivian Andes. It is dedicated to its adventurous discoverer, Mr. David Forbes.—T. R. J.]

Tentaculites supremus, n. sp. Pl. IV. fig. 11.

Nearly an inch long, diameter 2 lines, cylindrical, slowly tapering until near the apex; marked at intervals of about a line by cord-like ridges, strongly projecting, and often in pairs. Between these are close concentric annuli, or fine ridges, about thirteen in the space of a line.

The strong double ridges which ornament this species occur chiefly on specimens which have the rings more distant than others. They remind one much of the *Tentaculites* in the Wenlock strata of the Isle of Gothland. I believe this species to be a new one; it is a good deal like *T. ornatus*, Sow.

Locality. On the snowy ridge of Illampu, in company with *Homalonotus Linares.* A *Ctenodonta* and a Cup-coral are found with them.

Tentaculites Saienzii, n. sp. Pl. IV. fig. 12.

Tapering more rapidly than the last, and marked by numerous equidistant rounded rings [with no intermediate annuli?]. The want of annular striæ may be only a comparative character; but the regularity of the somewhat oblique rings seems to be specific.

Locality. It occurs in the grey shaly beds between the grits of Illampu, and is dedicated (by Mr. Forbes's request) to Señor Saienz, whose kind and efficient help was of great service to him in his explorations.

Smaller *Tentaculites* (fig. 13 *a*) occur in some of the slabs with the

Beyrichia above noticed; but they are probably the young of one of the foregoing species.

In Europe the strata in which *Tentaculites* are conspicuous are—Caradoc Sandstone, Llandovery rock, and Lower Devonian. In North America (New York) they appear to be more specially confined to the Devonian strata. They are known all over the world in Palæozoic rocks.

Burrows and Casts of Marine Worms.

Such impressions as these attract the attention of every close observer. The peculiar habits of marine worms, introducing, as they do, the sabulous matter from one stratum into the more clayey beds of another, have a special tendency to render the rock compact and tough-bedded. Mr. Forbes found the worm-markings of all sizes, both in the upper and lower beds of the Silurian rocks, and either as double burrows, single vermicular casts, or in groups, just as we find them in our own Ludlow, Devonian, and Carboniferous strata.

Orthis Aymara, n. sp. Pl. IV. fig. 14.

Variety (?) of *Atrypa palmata*, Morris and Sharpe, Quart. Journ. Geol. Soc. vol. ii. pl. 10. fig. 3: *Orthis palmata*, Sharpe, Trans. Geol. Soc. 2 ser. vol. vii. p. 207.

Circular, or only slightly transverse, strongly ribbed, with a very short, almost obsolete hinge-line; ventral valve convex, gibbous near the beak, with a depressed central rib near the margin; upper or dorsal valve flat, with two slightly raised ribs in the middle; ribs about 14, acute, no intermediate ones. Diameter about half an inch.

The above may stand as the obvious characters of this abundant species. As distinguished from the common southern form above quoted, the size is less, and the ribs not quite so prominent; but the chief difference is in the interior, which shows (in *O. palmata*) very strong dorsal teeth, and the ventral hinge-plates thick and short. Ours has but thin plates, and moderate-sized teeth.

I hardly see sufficient reason for considering *O. Aymara* a distinct form. It is very similar to the common African species above quoted, which also occurs at the Falkland Islands. The same fossil appears also to be frequent in the Lower Devonian rocks of Gaspé, Canada. But these localities being all Devonian, one is scarcely justified in uniting with these the Silurian shell from the Andes, if there be any structural differences. *Orthis palmata* is evidently a common shell; and such species have, as Edw. Forbes first showed, a wide range in time as well as geographically: *Atrypa reticularis* is a case in point, ranging, as it does, from the Middle Silurian to the Upper Devonian, and as a frequent shell throughout. The *O. Aymara* may, very probably, when we have more specimens, turn out to be the Silurian variety of a shell which attained a fuller development in Devonian times as *O. palmata*.

Localities. Valley of Millepaya, and other localities on the western side of the Andes.

[The Aymara Indians are supposed to have been the original inhabitants of these mountains. They still linger there, having never been completely conquered, and never having amalgamated with the Quichua or Inca race.—D. F.]

ORTHIS, sp. Pl. IV. figs. 15 & 16.

A small *Orthis*, which may be equally compared with varieties of the *O. elegartula*, Dalm., or with the Devonian forms, *O. opercularis*, &c., from the Eifel. The striæ seem to be pretty regularly interlined with smaller ones. In the absence of more perfect specimens, I do not give it a name. It is certainly not a young specimen of the *O. Humboldtii* of D'Orbigny.

Locality. Valley of Millepaya, and further south on the western slope of Illampu.

STROPHOMENA, sp.

A mere fragment or two of a small thin-shelled species, with fine radiating striæ.

Locality. Cotaña, about five miles south of the town of Sorata.

CUCULLELLA, sp. Pl. IV. fig. 17.

The transverse, oval and convex form of this shell reminds us of *C. ovata*, Sow., rather than *C. antiqua* of the same author. Both are Ludlow Rock species: but there are Lower Devonian forms very like them both in Britain and South Africa. The muscular plate extends, vertically, two-thirds across the shell.

Locality. West face of Illampu.

CTENODONTA (NUCULA), sp. Pl. IV. fig. 18.

This is figured, because it is rather common. Such transverse forms, concentrically striate, and a little antiquated in the lines of growth, are known in all Palæozoic formations.

Locality. Valley of Millepaya; also further south, on the western slope of Illampu.

ARCA? BROWNII, sp. Pl. IV. figs. 19 & 20.

Broad-oval, more than $2\frac{1}{2}$ inches wide, and $1\frac{3}{4}$ deep; the beak at the anterior fourth not very prominent, the hinge-line tolerably straight, not curved down. The posterior side is nearly as broad as the depth of the shell beneath the beak, slightly angulated along the posterior slope, and rounded at the posterior angle. The anterior side is somewhat produced, and straight along its hinge-margin. Surface marked by rather distant lines of growth, and covered all over the central parts of the disk by fine radiating striæ, sharply impressed, very unequal in size and depth, wavy in their course to the margin, and interlined by lesser ones. They are altogether absent on the anterior and posterior fourth. On our large specimen this effacement of the striæ is gradual; but in some others it is sudden, and the central striated area in these specimens is sunk below the general surface. These may be of a distinct species.

Fig. 20 represents a young specimen. The outline is much more rounded, however, if that be not due to pressure; and the duplicated striæ cover all the surface.

Locality. West slope of Illampu. [Fieldmarshal Brown, a well-known general of the War of Independence, and after whom this shell is named, showed much interest in these researches, and was of great assistance to the author of the foregoing memoir.—D. F.]

Bellerophon, sp.

About 1 inch wide, having a large body-whorl, a small spire, and the whorls not at all involute; umbilicus quite open, and the whorls sloping towards it. Striæ of growth arched backwards to the carinate margin, which, however, is obtuse, not sharp-edged.

Locality. Common enough in some hand-specimens from the west side of Illampu.

Patella or Pileopsis?

An extraordinary specimen of a subovate clypeiform shell, an inch and a half in its largest diameter, and rather more than an inch wide, has an excentric blunt umbo, and a rather wavy margin. The surface is covered with close concentric ridges, which show equally well on the external and internal cast. The general appearance is that of an oblique *Patella*, or rather one of the *Calyptræidæ*. But it is too imperfect to decide upon. Patelliform shells are known in the Silurian, but they are very rare.

Locality. West side of the Valley of Millepaya.

LOWER? SILURIAN.

Cruziana, D'Orbigny.

It seems hardly worth while to separate these obscure fossils into several genera while we know so little of them; but certainly they cannot all belong to one group. The distinctly grooved and bilobed form, which induced M. Cordier to apply the name *Bilobites* to them, is characteristic of the species described by D'Orbigny, and of some others found in N. America. The more elongate strap-shaped species found in Europe have already received names from M. Rouault in his memoirs on the Silurian Rocks of France. And the species here figured belong to such various plans of form that, if we only knew a little of the nature of the bodies in question, we should be bound to give them separate names; at present I only propose one for the sagittate forms—*Boliviana*. Mr. Forbes did not meet with either of D'Orbigny's species, which, from that author's description, came from Lower Silurian beds*. Those here described are also the lowest fossils in the section.

* "C'est le premier corps organisé qui se montre au-dessus des phyllades schistoïdes, dans les phyllades micacés brunâtres."—Voyage, &c. vol. iii. part 4 (Paléontologie), p. 31. Mr. Forbes thinks, however, that there is no evidence of their being so low in the series.

Cruziana Cucurbita, n. sp. Pl. V. figs. 4, 5, & 6.

Three inches long, elongate, clavate, curved into a shape more or less sigmoid, subcylindrical in section, compressed; rounded at the anterior end, tapering posteriorly; smooth, except a few irregular wrinkles, but with a raised longitudinal rib throughout (down each side?).

I am not sure whether the raised rib which runs from end to end of these shapeless masses is an external marking, or arises from an internal hard cylinder. Fig. 6 shows some irregular transverse wrinkles; but, except these, there is no marking whatever to distinguish this form, which may be recognized by its blunt clavate shape, like many of the gourd-fruits, whence the name.

Locality. Very plentiful on the surfaces of grey schist. Valleys of Unduavi and Aceromarka.

Cruziana Unduavi, n. sp. Pl. V. figs. 7 & 8.

Three or four inches long, subcylindrical, but often flexuous, slowly tapering. Surface marked with numerous (9 or 10) longitudinal ribs, which run for short distances only, and alternate, leaving some parts smooth. The general direction of the ribs is longitudinal, but wavy.

Localities. Valleys of Aceromarka and Unduavi, where it is most abundant.

Boliviana, gen. nov.

Form obcordate or sagittate, tuberculate or ridged, without a central furrow, and produced behind into two barbs or wing-like appendages. (A peduncle or stem occurs in some species.)

These broad arrow-shaped forms differ so much from the true *Cruziana*, that it does not seem premature to separate them. (I leave the elongate forms at present all in one genus.) And the general term *Bilobites* may still be conveniently used for the whole group, though not now accepted as a generic term.

Boliviana Melocactus. Pl. V. fig. 9.

Three-quarters of an inch long, obcordate, deeply notched behind, and pointed and produced backward on each side. Surface gently convex, rising into a ridge along the median line, which projects a little in the middle of the deeply emarginate posterior edge. Six longitudinal ridges, narrower than the central one, run along the whole length, with irregular tubercles on them, arranged so as to form tranverse rows, seven or eight on each side.

A rough resemblance to the mammillated plants so common in the region of the Andes suggests the name.

Locality. Valley of Aceromarka, north-eastern slope of Illimani.

Boliviana proboscidea. Pl. V. fig. 10.

This appears to be only about half of the disk, and it is therefore described as if the longitudinal ridge (a) were central. An inch and a half long, narrow-sagittate, lanceolate, convex; with a very prominent central ridge, produced behind into a thick blunt spine. Posterior edge doubly emarginate, but with the angles scarcely at all produced. Six longitudinal ribs on each side of the central one, all closely tuberculate, so as to form transverse rows.

The projecting mass is supposed to be the stem, and is nearly as long as the frond, very thick, obtuse, attached to the posterior margin, and shaped like the siphon-sheath of a bivalve shell.

Locality. Valley of Aceromarka.

Boliviana bipennis. Pl. V. fig. 11.

Mr. Forbes observed the other part of this specimen in the rock, but could only detach one half. The outline is therefore added to our figure.

Frond semioval, emarginate behind, gibbous at the sides, and with the posterior angles produced into strong divergent tapering spines. Surface marked by ridges and furrows parallel to the curve of the front and back margins. Spines also furrowed near the base. Stem (apparently attached) long filiform.

Locality. Valley of Unduavi, eastern slope of the Andes.

Summary.

The number of species that we recognize in this collection, made with so much perseverance and at great personal hazard, are—

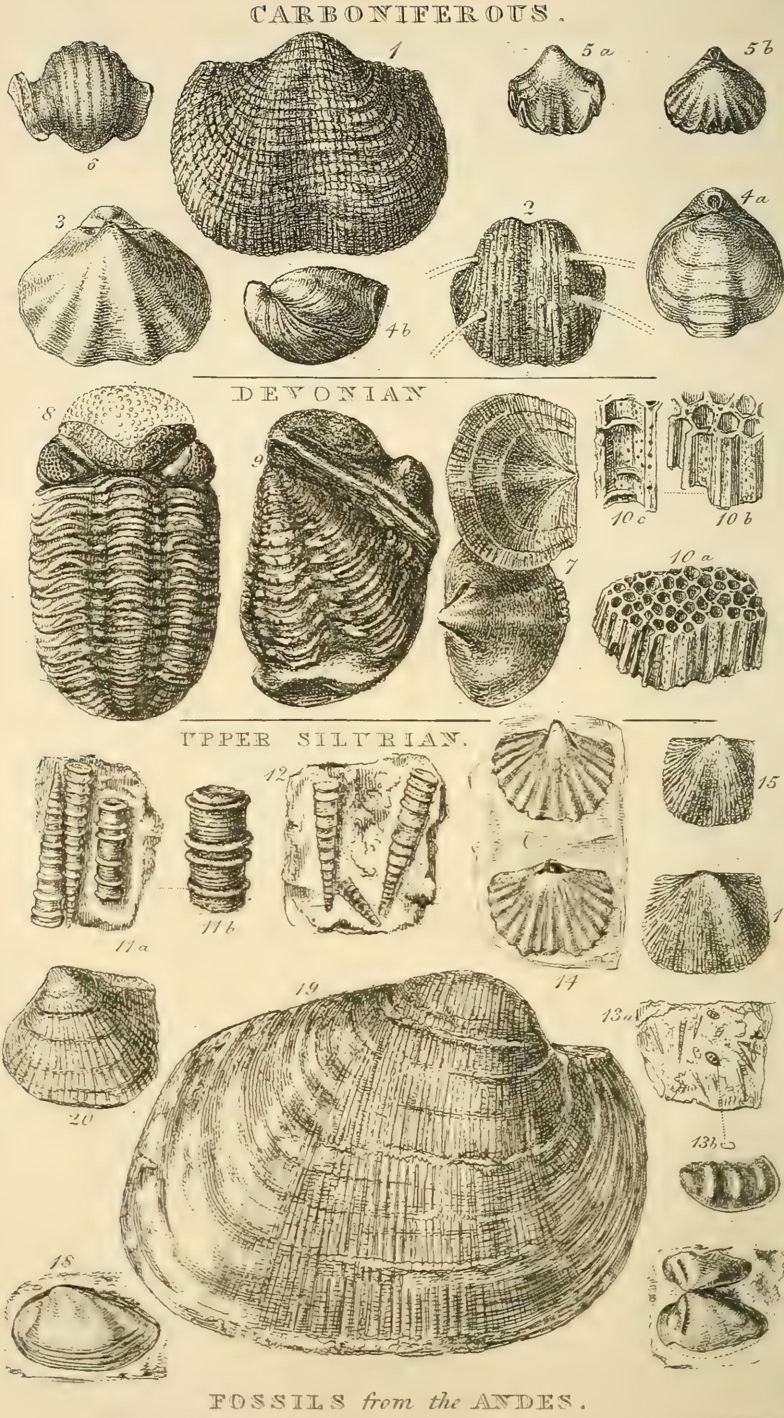
5 Lower? Silurian (Bilobite-schists).
14 Upper Silurian (grey sandy schists and sandstones).
3 Devonian.
13 Carboniferous.

D'Orbigny's collection of Silurian fossils contained 10 species, of which none have occurred to Mr. Forbes. They are—

Cruziana rugosa.
—— furcifera.
Orthis Humboldtii.
Lingula marginata.
—— Muensterii.
—— dubia.
Graptolites dentatus.
Phacops (Calymene) Verneuilii.
—— (C.) macrophthalma?
Asaphus Boliviensis.

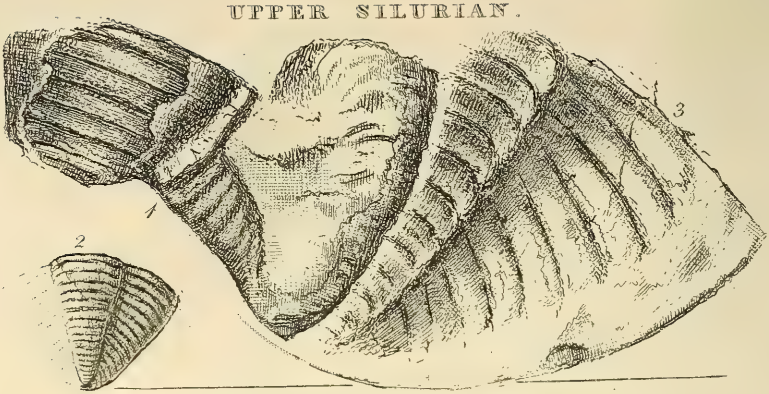
There is some doubt about both his species of Phacops. They are probably Devonian.

Adding these to our list, we obtain 27 or 29 Silurian species for the Central Andes, belonging to a fauna specifically different from that of any other quarter of the world. I venture without hesitation to assert that the identifications by D'Orbigny with European forms, where I am acquainted with the species, are wrong. I am obliged to say this much, since that distinguished author has fearlessly united things which differ by the most obvious external characters, and has lent the sanction of his great reputation, on such evidence as this, to a former community of species, and an equable diffusion of heat. In regard to the Carboniferous forms, where M. D'Orbigny is unwilling to allow more than a close analogy between the two continents, I am again compelled to differ from him, but it is in an opposite direction.

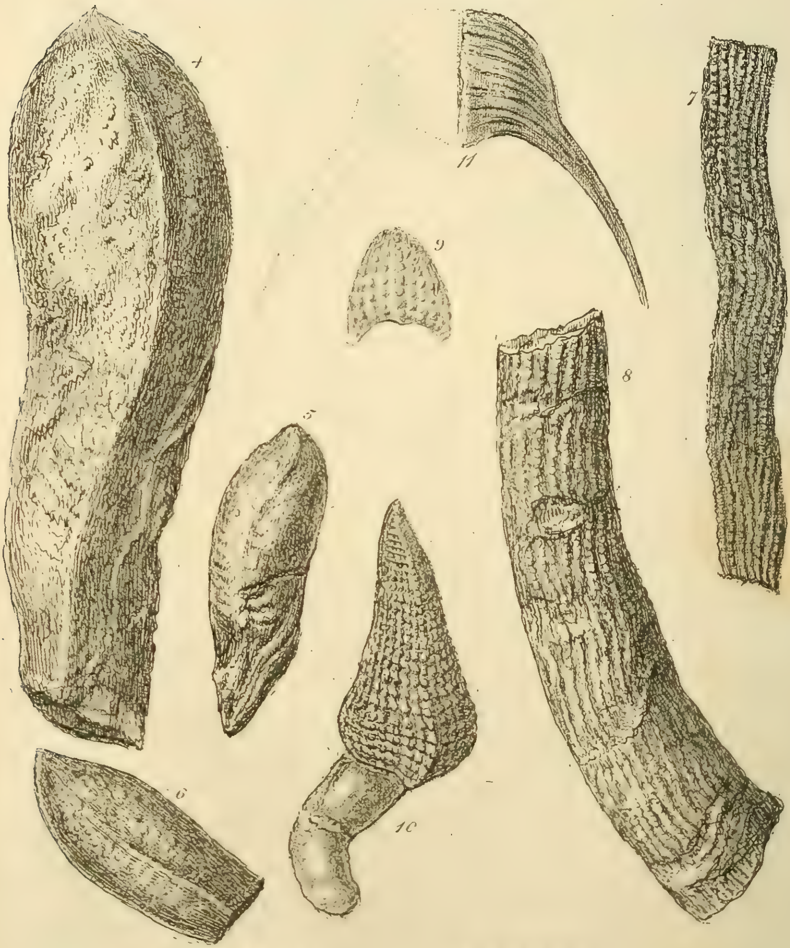


FOSSILS from the ANDES.

UPPER SILURIAN.



LOWER? SILURIAN.



FOSSILS *from the* ANDES.

G. B. Sowerby.

EXPLANATION OF PLATES IV. & V.

Illustrating Mr. Salter's paper on some Palæozoic Fossils from the Bolivian Andes.

Plate IV.

Fig. 1. Productus semireticulatus, *Martin.* Isthmus of Copacabana.
2. P. Longispina, *Sow.* Isthmus of Copacabana.
3. Orthis Andii, *D' Orb.* Santa Cruz.
4. Athyris subtilita, *Hall.* Isthmus of Copacabana.
5. Rhynchonella, sp. Santa Cruz.
6. Bellerophon; like *B. Urii*, Fleming. Isthmus of Copacabana.
7. Orthis, sp. Oruro.
8. Phacops latifrons, *Bronn.* Oruro.
9. Ph. Pentlandii, *Salter.* Aygatchi.
10. Favosites (?), sp. Oruro.
11. Tentaculites supremus, *Salter.*
12. T. Saienzii, *Salter.*
13 *a.* Tentaculites, sp., and Beyrichia Forbesii, *Jones.*
13 *b* & 13 *c.* Beyrichia Forbesii, *Jones.* } Illampu.
14. Orthis Aymara, *Salter.*
15, 16. Orthis, sp. } Valley of Millepaya.
17. Cucullella, sp. Illampu.
18. Ctenodonta (Nucula), sp. Valley of Millepaya.
19. Arca (?) Brownii, *Salter.* Fig. 20. Young specimen. Illampu.

Plate V.

Fig. 1 & 2. Homalonotus Linares, *Salter.*
3. Homalonotus, sp. } Illampu.
4, 5, & 6. Cruziana Cucurbita, *Salter.*
7 & 8. C. Unduavi, *Salter.*
9. Boliviana Melocactus, *Salter.*
10. B. proboscidea, *Salter.*
11. B. bipennis, *Salter.* } Valleys of Aceromarka and Unduavi.

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3. *On a* New Species *of* Macrauchenia (M. Boliviensis). By Thomas H. Huxley, F.R.S., Sec. G.S., Professor of Natural History, Government School of Mines.

[Plate VI.]

The vertebrate remains obtained by David Forbes, Esq., F.R.S., F.G.S., from the mines at Corocoro, under the circumstances detailed in his paper "On the Geology of Bolivia and Southern Peru," consist of the following parts of the skeleton of apparently one and the same Mammal:—1. A portion of the right maxilla and palate, with fragments of grinding teeth. 2. Rather more than the right half of the occipital portion of the skull. 3. A middle cervical vertebra, nearly entire. 4. A fragment of a posterior lumbar vertebra. 5. A small portion of a right scapula. 6. A crushed fragment of the proximal end of an ulna. 7. Part of the proximal end of the left tibia. 8. The entire left astragalus, and part of the right astragalus.

The bones are all in the same, and that a very peculiar, mineral condition—the Haversian canals being for the most part filled up with threads of native copper; so that the fossils are not only exceedingly dense, but, in consequence of their internal flexible metallic support, their thinner and more delicate parts bend, rather than break, when force is applied to them.

The characters of the cervical vertebra and of the astragalus, which are fortunately the best-preserved of all the fossils, at once demonstrated the remains to belong to the genus *Macrauchenia* (Owen), while the entire absence of epiphysial sutures in the vertebræ and the long bones, and of similar indications of immaturity in the fragment of the skull, proved the animal to have attained its adult condition. The vertebra and the astragalus, however, have not more than half the size of the corresponding bones of the species, *M. Patachonica*, discovered by Mr. Darwin, and described by Professor Owen in the 'Appendix to the Voyage of the Beagle'; and as, in addition, these and the other bones present different proportions from those of the Patagonian species, I have no hesitation in regarding the fossils collected by Mr. Forbes as the remains of a distinct species, for which I propose the name of *Macrauchenia Boliviensis*. It will be convenient to commence the description of these fossils with those parts upon which the diagnosis of the species may be most safely rested, viz. the cervical vertebra and the astragalus.

The cervical vertebra (Plate VI. fig. 1).—The great length of the centrum of this vertebra, the peculiar form of its transverse processes, and the absence of perforations for the vertebral arteries in them are characters which, in the present state of knowledge, oblige the anatomist at once to refer it either to one of the existing *Camelidæ* or to the genus *Macrauchenia*; while the two strong, converging ridges which mark the posterior half of the under surface of the vertebra, and meet to form a single ridge, which dies away anteriorly in the middle of that surface, together with the slight concavity of both the posterior and the anterior articular faces of the centrum, are decisive in favour of the latter alternative. In fact, the excellent description of the cervical vertebræ of *Macrauchenia Patachonica* which has been given by Professor Owen applies so well to that of *M. Boliviensis*, that, referring to the paper in the 'Appendix to the Voyage of the Beagle,' already cited, for a general account of the characters of Macrauchenian vertebræ, I shall content myself with pointing out the resemblances and differences of the Bolivian from the Patagonian *Macrauchenia*, and from the existing *Aucheniæ*. The dimensions of the centrum of the cervical vertebræ of the two *Macraucheniæ*, and of the fourth cervical of a Guanaco and of a Vicugna in the College of Surgeons' Museum are as follows:—

	M. Boliviensis.	*M. Patachonica.*	*Guanaco.*	*Vicugna.*
	in.	in.	in.	in.
Length..............	3·8	6·6	4·6	4·0
Width of anterior face	1·1	3·2	1·1	·8
Width of posterior face	1·25	3·4	1·3	1·0

Thus it appears that the centrum of the cervical vertebra of *Macrauchenia Boliviensis* is far more slender than that of *M. Patachonica*; for, while the length of the former is to that of the latter as $1 : 1\frac{7}{9}$, the transverse diameters of the anterior faces of the centra of the two species are, nearly, as 1:3. The cervical vertebra of the new species is, absolutely, rather shorter than the fourth cervical of the Vicugna; but, relatively to its width, it is much shorter and stouter than this bone in either the Guanaco or the Vicugna. There are no longitudinal ridges on the surface of the vertebra below the prezygapophyses, in which respect *M. Boliviensis* differs from *M. Patachonica*, and approaches the *Aucheniæ*. The anterior articular facet of the centrum is concave from above downwards, in consequence of the projection of the thickened and convex lower third of that face; the posterior facet is not only concave from above downwards from a similar cause, but is also concave from side to side. The concavity of both articular facets is greater than in *M. Patachonica*, and the present species departs, in these respects, more widely than the latter does from the *Aucheniæ*.

The astragalus (Plate VI. fig. 2).—This bone is, again, quite that of the Patagonian species in miniature, differing chiefly in the proportions of its dimensions, as shown by the subjoined table:—

	Macrauchenia Boliviensis.	*M. Patachonica.*	*Guanaco.*	*Vicugna.*
	in.	in.	in.	in.
Length	1·45	3·3	1·6	1·3
Greatest width ..	1·2	2·7	1·2	·85
Greatest depth ..	·85	2·15	·95	·8

If we take the lengths of the astragali, it will be observed that their proportions in the Bolivian and Patagonian *Macraucheniæ* are not the same as those of the cervical vertebræ. The astragali bear the ratio of $1 : 2\frac{1}{3}$, while the cervical vertebræ gave $1 : 1\frac{7}{9}$. Furthermore, the proportions of length, width, and depth in the two astragali are different. Like the cervical vertebra, the astragalus of *M. Boliviensis* is a, relatively, stouter bone than that of the Vicugna; though instead of being shorter it is a little longer, occupying a position, in point of absolute length, between the astragalus of the Vicugna and that of the Guanaco. As the astragalus thus yields results agreeing very well with those given by the cervical vertebra, we may safely assume that not only the absolute size, but the proportions of the body of *Macrauchenia Boliviensis* were nearly those of the existing Llamas, and differed widely from those of the heavy and huge *Macrauchenia Patachonica.*

The tibia.—What remains of the bones of the hind leg confirms this view of the proportions of *Macrauchenia Boliviensis*. I have the proximal end of the left tibia, minus the fibula, and with the outer articular condyle broken away. Below this point, the outer edge and surface of the fragment are uninjured, and the posterior face is in good preservation, but the internal face is somewhat crushed. The muscular ridges on the posterior face are as well marked as in the skeleton of the Guanaco, and far more distinct than in that of the Vicugna, yielding additional evidence of the adult condition of the animal, to that afforded by the absence of epiphyses.

The antero-posterior diameter of the tibia, measured from the posterior edge of the internal articular facet to the anterior edge of the crest of the tibia, is, in—

M. Boliviensis.	*M. Patachonica.*	*Guanaco.*	*Vicugna.*
in.	in.	in.	in.
2·4	5·4	2·3	2·1,

so that the depths of the proximal ends of the tibiæ of the two *Macrauchenicæ* have the ratio of 1 : $2\frac{1}{4}$, which corresponds very well with the proportions of the astragali, and confirms the conclusions already arrived at, as to the relative lightness of the limbs of this species in comparison with those of *M. Patachonica*, and as to the similarity of the proportions of the Bolivian species to those of the Llamas.

What remains of the outer edge of the tibia is sufficient to prove that the fibula must have remained unanchylosed to the tibia for a much greater distance than in the Patagonian species. From the manner in which the outer tuberosity of the proximal end of the tibia is broken off, I am inclined to suspect that the fibula was anchylosed to it at this point; and perhaps, as in the *Auchenicæ*, its proximal end was represented only by a bony style.

The scapula is represented merely by a mutilated fragment, comprising the glenoid cavity and the adjacent parts. The spine of the scapula is broken off, and the glenoid cavity is somewhat distorted by the bending of one of its edges; but enough remains to show that the bone must have agreed with the scapula of *Macrauchenia Patachonica* in all essential respects, and that it therefore differed very widely from that of the *Auchenicæ*. In size, however, it nearly corresponded with the corresponding bone in the latter animal; for the greatest diameter of the glenoid cavity is 1·2 in., the same measurement in the Vicugna being 1·0, and in the Guanaco 1·6.

The ulna.—The fragment of the ulna, consisting of part of the olecranon process and of the sigmoid cavity, is so crushed, that I can only affirm its general agreement in form with that of *Macrauchenia Patachonica*, and in size with the same bone in the Llamas.

The lumbar vertebra.—Of bones referable to this region of the body, again, there is but a single fragment, of value only so far as it confirms the conclusions arrived at by the examination of the more perfect fossils. It corresponds very well with the posterior half of the centrum of the penultimate lumbar vertebra of *M. Patachonica* in form, and with the corresponding vertebra of *Auchenia* in size; but the crest into which the middle of its under surface is raised, and which is still sharper than that in the Patagonian species, diagnosticates it at once from any of the lumbar vertebræ of the Llamas.

The transverse diameter of the articular face is 1·1 in., its vertical diameter 0·9. The corresponding measurements of the antepenultimate lumbar vertebra of *M. Patachonica* are 3·0 in. and 2·1; so that, as in other bones, the proportions of diverse diameters of the same bone are not the same in the two species. But as the transverse diameters of the cervical vertebræ of the two species are nearly as 1 : 3, and the transverse diameters of the lumbar vertebræ are, also, nearly in the ratio of 1 : 3, it would seem as if the different regions of the vertebral column of the two species exhibited the same proportional correspondence to one another.

The skull.—As no part of the skull of *Macrauchenia Patachonica* has yet been discovered (with perhaps the exception of part of the lower jaw), a great interest attaches to every fragment which promises to throw light upon this part of its organization; and I therefore make no apology for dwelling at some length upon the characters of the two very imperfect and mutilated portions of the cranium which turned up among the specimens submitted to me by Mr. Forbes.

The one of these (Plate VI. fig. 3) consists of rather more than half of the occipital segment of the skull, and exhibits the whole of the supra-occipital bone, with its strong occipital crest, a part of the parietal with the sagittal crest, the greater part of the right paramastoid process, and the entire right occipital condyle.

As I have already remarked, the sutures are obliterated: and this is true, not only of those which ordinarily exist between the elements of the occipital bone in young mammals, but of the lambdoidal suture, which usually persists for a longer period. The occipital foramen must, when entire, have had a depressed-oval form, the short, vertical axis of the oval being about 0·6 of an inch long. The face of the bone above it inclines upwards and forwards, at an angle of about 50° with the base of the skull, and presents a sharp ridge in the middle line, on either side of which the surface of the supra-occipital element slopes with a slight convexity outwards and forwards, at the sides and below; while, above, it becomes concave by passing almost vertically upwards in the middle line, and laterally, bending upwards and backwards at a right angle with its previous inclination into the occipital crest.

This crest is nearly 0·2 inch thick at the sides, and becomes still thicker in the middle line, where it joins the sagittal crest. It is 1·1 inch in diameter at its widest part, and about half an inch high. Its contour is that of a parallelogram, with its angles rounded off, and the middle of its upper side rather truncated. The lateral portions project backwards rather more than its centre; so that, while, supposing the basi-occipital to be horizontal, a vertical line drawn through the posterior edge of that bone would nearly coincide with the contour of its central part, it would pass a little anterior to the plane of the lateral extremities of the crest. Inferiorly, the thick lateral portions of the crest divide into two ridges; the posterior of which turns slightly inwards and comes to an end, while the anterior, much sharper at its edge, passes forwards and outwards, and becomes continuous with the sharp ridge in which the paramastoid process terminates externally.

Behind this ridge, between the paramastoid process, the occipital condyle, and the lateral convexity of that part of the occipital bone which lies above the foramen magnum, there is a deep fossa, which is divided into two portions by a transverse ridge, extending from the outer and upper part of the condyle to the posterior and inner face of the paramastoid process. The large precondyloid foramen (probably somewhat enlarged accidentally) opens into the lower and anterior division of the fossa, beside the condyle, and about $\frac{1}{6}$th of an inch behind its anterior inferior boundary. The upper boundary of the foramen magnum is almost straight, and its summit is below the level of the superior edge of the condyle (when the base of the skull is horizontal). The condyle is divisible into an upper, smaller, obliquely ascending, and a lower, more nearly horizontal facet. The line of junction between the two, forming the posterior limit of the condyle, is rounded off and is directed obliquely outwards and upwards. The moderately convex upper facet looks upwards, backwards, and but very slightly outwards. It is broad above, where its transverse diameter amounts to nearly half an inch, and tapers off gradually to a point below and internally.

The inferior facet, less curved than the other, is 0·6 of an inch wide behind, hardly more than half that in front, and fully 0·8 of an inch long. It is slightly convex from side to side, and from behind forwards, posteriorly, where it looks downwards and outwards; convex from side to side, and slightly concave from behind forwards, in front, where it is directed more horizontally downwards. Its anterior narrow end has a sharply defined rounded margin, which can be traced to the anterior boundary of the occipital foramen; so that the occipital condyles certainly did not coalesce in the middle line.

The paramastoid process is broken off rather above the level of the lower boundary of the occipital condyle; but, from the thinness of the fractured edge, I imagine it did not extend much further. It is broad and flattened, the direction of its greatest diameter being from behind and without, inwards and forwards. Its posterior face is directed as much inwards as backwards, and its outer margin is sharp, except towards the lower end, where it becomes rounded. Internally, it thickens before rejoining the exoccipital, in front of, and external to, the precondyloid foramen. The upper part of its anterior and external face is evidently rough and has united with the mastoid, now completely broken away; but it is difficult to say how far downwards the sutural face extended. The posterior boundary of the jugular foramen is preserved on the inner side, and in front of, the thick inner edge of the paramastoid.

The sagittal crest is continued forwards from the triangular prominence common to it and the occipital crest, and at once becomes very thin and sharp. It is broken off at a very short distance from its commencement, and at this point it is a quarter of an inch high. Its superior margin is not parallel with the contour of the middle line of the parietal region, but has a more marked upward inclination, so as to lead one to suppose that the crest rose to a considerable height in the middle of the sinciput,—a conclusion which is strengthened by the great thickness of the parietals (of whose median suture no trace is visible) in the middle line. The transverse section presented by the anterior broken edges of these bones is, in fact, triangular, and the height of the triangle from its apex, which corresponds with the base of the crest, to its base (the concave inner wall of the cranium) is nearly 0·4 of an inch.

In viewing the fragment of the occiput from within, one is surprised by the great thickness of the supra-occipital region, the bone immediately above the middle of the occipital foramen being half an inch thick. A well-marked ridge, defining the interior boundary of the cerebellar fossa, is continued downwards, forwards, and outwards, from the anterior boundary of the thick roof of the occipital foramen. There is no venous canal traceable above the inner aperture of the precondyloid foramen.

If the occiput of *Macrauchenia Boliviensis* be restored by reversing the outlines of the right half (as in Pl. VI. fig. 3), thus supplying the wanting left moiety, the following measurements may be obtained. Side by side with them I give the corresponding measurements of the skull of the Vicugna:—

	M. Boliviensis. in.	*Vicugna.* in.
Transverse diameter of the occiput from the outer edge of one paramastoid to that of the other	1·9	2·25
Ditto from the outer edge of one occipital condyle to that of the other.	1·5	1·5
The transverse diameter of the occipital foramen..................	·7	·7

It will be observed that the two series of dimensions correspond very closely, the two latter being identical, while the *Macrauchenia* appears to have had even a narrower skull than the Vicugna. In form, the occiput of *Macrauchenia* agrees better with that of the Llamas than with that of any other ungulate animal with which I have compared it.

Thus, in an old Guanaco I find an equally well-marked ridge in the middle line of the supra-occipital element; the occipital crest is equally prominent, though not so stout; the sagittal crest is as well marked, thin and sharp, and, as in *Macrauchenia*, its superior edge ascends. There is a fossa between the occipital condyle and the paramastoid, similar in form to that in *Macrauchenia*, though much shallower. The occipital condyles are very much alike; and their relation to the precondyloid foramina is the same in both cases. The paramastoid has the same proportional breadth; and its greatest diameter is, in both cases, directed from without and behind, inwards and forwards: in both cases its inner edge is peculiarly thickened. Again, the paramastoid of the *Auchenia*, like that of the fossil, is very short, its apex hardly extending below the level of the occipital condyle.

The occiput of *Macrauchenia*, on the other hand, differs from that of *Auchenia* in the much greater thickness of the supra-occipital, which in the *Macrauchenia* has fully double the thickness of the same region in an old Guanaco, whose skull is much larger—in this respect approaching the Sheep and some other Ruminants, which have this bone very thick. The supra-occipital, also, is much higher, in proportion to its width, in *Macrauchenia* than in *Auchenia*; its lateral contours are parallel, and not divergent outwards and upwards. There is nothing in the *Macrauchenia* resembling the deep notch between the supra-occipital and the base of the paramastoid, into which a part of the mastoid fits in *Auchenia*. In contour, in fact, the occiput of the *Macrauchenia* resembles that of the *Palæotherium* more nearly than that of any other Mammal. But, on the whole, I think it must be admitted that the resemblance of the back of the skull of the *Macrauchenia* to that of *Auchenia* is sufficiently close to justify the conclusion, that the predominance of the Cameline type, so marked in the neck, was maintained in the head of the extinct Mammifer.

The fossil which remains for description (Plate VI. fig. 4) consists of two fragments of the matrix (*a* and *b*), which fit together, and to which adhere certain portions of the upper jaw and palate, together with the fractured remains of three grinding-teeth and part of the alveolus of a fourth, all of the right side, and in a continuous series. The alveoli and part of the crowns of these teeth are contained in the larger fragment of matrix,—the smaller fragment fitting against the larger and the teeth which it contains, and exhibiting the impressions of the grinding surfaces of three teeth and of their inner faces, a portion of dental substance adhering to the latter, in the case of the two anterior teeth. Of the hindermost tooth nothing is left but the impression of one fang.

The impression of the grinding surface of the first tooth is nearly four-tenths of an inch long, convex from before backwards, concave internally: the outer boundary of the impression is broken away, a fragment of dental substance adhering to the posterior part of its inner face. The part of the larger portion of the matrix (*a*) which should contain the alveolus of this tooth is absent. The antero-posterior extent of the coronal impression of the second tooth is a little more than 0·4 of an inch; it is concave from before backwards externally, nearly flat internally, and shelves with a slight convexity upwards and inwards. The inner boundary of the impression is, as in the preceding case, markedly concave; and a much larger fragment of tooth-substance adheres to it. The outer boundary of the impression is broken away, but much more in front than behind, where its width is fully 0·4 of an inch. The impressed line which separates this impression from the next is convex forwards. Corresponding with this impression there are, in the larger fragment of matrix, an almost entire conical posterior fang, about 0·4 of an inch long, lodged in a complete bony alveolus, whose outer wall is broken away, and the posterior half of a similar alveolus for an anterior fang: there is no trace of a third alveolus or fang; and, indeed, there seems to be no room for one. The fang which exists is connected below with a portion of the crown; but this is so broken, that all that can be remarked of it is its marked internal convexity.

The coronal impression of the third tooth is half an inch long; like the preceding, its face shelves upwards and inwards. The posterior part of its outer margin is broken away; but it is clear that this crown was quite as wide as that which preceded it, if not wider;

the surface appears, however, to have been more evenly flat. The inner perpendicular face of the impression presents two concavities, separated by a slight ridge.

More of this tooth is preserved than of any other; the outer wall of the maxilla is, for the most part, preserved over it, and encloses the alveoli of two external fangs. There is evidently at least one, and perhaps two, internal fangs. The whole thickness of the inner and posterior part of the crown is preserved, and the posterior and inner half of its worn face; the rest of the tooth is broken away. The posterior and outer fang, partially exposed, is 0·3 of an inch long, conical, and slightly inclined backwards, as well as upwards and inwards. The crown, where it joins the fang, is 0·4 of an inch long; so that it must have widened a little below. The vertical height of the crown of the tooth posteriorly and internally is hardly more than 0·15; anteriorly and internally it is broken; but, when entire, it had a height of at least 0·2. The inner surface of the tooth is divided into two tolerably well-marked subcylindrical faces, which correspond with the impressions on the inner wall of the coronal impressions.

The outer moiety of the crown is altogether broken away; the inner moiety, broken anteriorly, exhibits in its posterior half a smoothly worn facet, concave from before backwards, and inclined not only downwards but slightly backwards. A narrow fringe of enamel appears to surround the worn dentine of this face, which is wider in the middle than at the two ends. The true outer face of the enamel can be traced from the inner face of the tooth, continuously, round the posterior boundary of this worn facet, and as far as its most dilated portion on the inner side. It is concave outwards, and presents a slight inflexion midway between the posterior end of the facet and its middle dilatation. Beyond the dilated middle of the facet, its enamel-wall seems to have been united with that of the opposite half of the tooth; but it is traceable forwards, becoming concave externally, past the anterior end of the worn facet, to the anterior margin of the tooth, where it bends round and again becomes continuous with the enamel of the inner face.

This tooth, therefore, appears to have possessed an internal division, elongated from before backwards, surrounded by a narrow band of enamel,—having its inner contour produced into two convexities, separated by a slight vertical depression, while its outer wall presents two concavities, separated by a slight ridge which lies rather behind the level of the depression on the inner face. By use, the posterior part of this division wore down into a facet, concave from before backwards, and separated, by a transverse ridge, from the facet in front of it. A longitudinal fossa separated the posterior moiety, at least, of this division of the tooth from the outer division.

Imperfect as is this fragmentary grinder, certain important conclusions may, I conceive, be very safely drawn from its structure. The predominance of the longitudinal, to the exclusion of transverse valleys and ridges in the crown of the tooth, the distinct, though not strongly marked, crescentic form of the internal division of the tooth, and its short crown, remove it from the teeth of any known

Perissodactyle Mammal, and lead one, at once, to seek its analogue among the *Artiodactyla*; and of these the Ruminants alone, so far as I know, offer anything like it. The inner grinding-surface of any true molar of a Ruminant, however, exhibits two ridges and three depressions; while that of the *Macrauchenia* has only one ridge, with a concave shelving depression behind, and doubtless, in the perfect condition, another in front; in other words, it has the contour exhibited by one of the hinder premolars of a Ruminant. The inner division of a posterior premolar of *Auchenia* has its convex inner surface undivided by any vertical depression; and its outer, posterior margin exhibits no marked inflexion: but such an inflexion exists in the corresponding teeth of the Giraffe and of many Deer, in some of which latter a vertical groove, dividing the inner face into two convexities, may also be noted.

I am of opinion, therefore, that the tooth in question is a posterior premolar, and that it was constructed upon the Ruminant type. In this case, however, the dentition of *Macrauchenia* must have departed widely from that of the *Camelidæ*; for there were certainly two teeth with flat grinding crowns in front of that just described, which would give, at least, three premolars in all, or as many as are found in ordinary Ruminants.

I am strengthened in the conviction that there were as many as three premolars, by the rest of the structure of this interesting fragment. Within the series of teeth just described, in fact, it presents a considerable portion of the roof of the palate, some of whose bony matter remains. At a distance of half an inch from the inner wall of the posterior premolar, a longitudinal sutural line traverses the whole length of the palatine surface, and ends abruptly (in consequence of the fracture of the matrix) as well behind as in front. Its posterior end is 1·2 of an inch behind a transverse line drawn at the level of the posterior margin of the last premolar. Opposite and behind this tooth, the right half of the palate is marked by what might hastily be taken for a suture, but which is nothing but a fracture. Behind it, and 0·9 of an inch in front of the posterior end of the longitudinal suture, two curved transverse lines, convex forwards, which I believe to be the maxillo-palatine sutures, pass into the longitudinal suture.

Thus, it is clear that the palate must have extended back for 1·2 of an inch behind the third grinding-tooth.

Supposing this tooth to have been succeeded by three others whose length, if they were molars, would be probably between 0·6 and 0·7 of an inch, it follows that the posterior margin of the palate must have extended, at least, as far back as the posterior margin of the second molar. This is further than it extends in the *Aucheniæ* (the very forward extension of whose palatine aperture is exceptional among the *Artiodactyla*), but it is not so far as in the Camel, where the posterior boundary of the palate is opposite the middle of the last molar*.

* The attempt to differentiate the *Artiodactyla* and *Perissodactyla* absolutely by the position of the posterior margin of the bony palate is fallacious. On an

This backward extension of the palate is, so far as it goes, in favour of the view to which the consideration of the dentition and the structure of the occiput leads, viz. that the cranium of the *Macrauchenia* was constructed upon an essentially Artiodactyle type.

The following are the dimensions of the palate and teeth of *Macrauchenia Boliviensis*, and those of the corresponding parts in the Vicugna:—

		Macrauchenia.	*Vicugna.*
Width of palate inside the grinding teeth*	about	1·0	1·25 (at widest).
Antero-posterior length of four grinders....	more than 2·0 less than 2·5		2·2

The narrower palate of the *Macrauchenia* agrees with its narrower occiput, while it exhibits the same general correspondence with the Vicugna as has been met with in the limbs and vertebræ.

Thus I conceive that an attentive examination of these scanty remains is sufficient to prove that, when they were imbedded, there lived in the highlands of Bolivia a species of *Macrauchenia* not half as large as the Patagonian form, and having proportions nearly as slender as those of the Vicugna, with even a lighter head; and it is very interesting to observe that, during that probably post-pleistocene epoch, a small and a large species of more or less Auchenoid Mammal ranged the mountains and the plains of South America respectively, just as at present the small Vicugna is found in the highlands, and the large Guanaco in the plains of the same continent†.

The structure and geological date of the genus *Macrauchenia* may serve, if taken together, to point an important palæontological moral. Professor Owen, in the able memoir cited above, has clearly pointed out the remarkable combination of Artiodactyle and Perissodactyle characters exhibited by *Macrauchenia*, which unites the eminently characteristic cervical vertebræ of the Artiodactyle *Camelidæ* with the three-toed fore foot and the triply trochantered femur of the

average it is doubtless true that the bony palate extends further back in the former than in the latter; but the bony palate extends to a line joining the anterior edges of the last molars in *Hyrax*; while in the full-grown Guanaco, a similar line is 0·4 of an inch behind the posterior boundary of the palate.

* The six grinding-teeth of the lower jaw, which Professor Owen has provisionally referred to *Macrauchenia* (British Association Reports, 1846), are said to form a series 9 inches long. A series of six such teeth of the lower jaw of *Macrauchenia Boliviensis* could not have exceeded 4 inches in length, and was probably shorter. Under these circumstances, the heads (as measured by the teeth) of the two species would be in nearly the same proportion as their astragali, and in very different proportions from their cervical vertebræ. This is not improbable; for the Vicugna has a much lighter head than the Guanaco, if the cervical vertebræ be taken as the standard. The length of the fourth cervical of the Vicugna is to that of the same bone in the Guanaco as $1 : 1\frac{1}{7}$, while the length of the head in the two is as $1 : 1\frac{1}{2}$.

† As the Guanaco ranges into the highlands, it may not be a too sanguine expectation to hope for the future discovery of remains of the great *Macrauchenia*, also, in Bolivia.

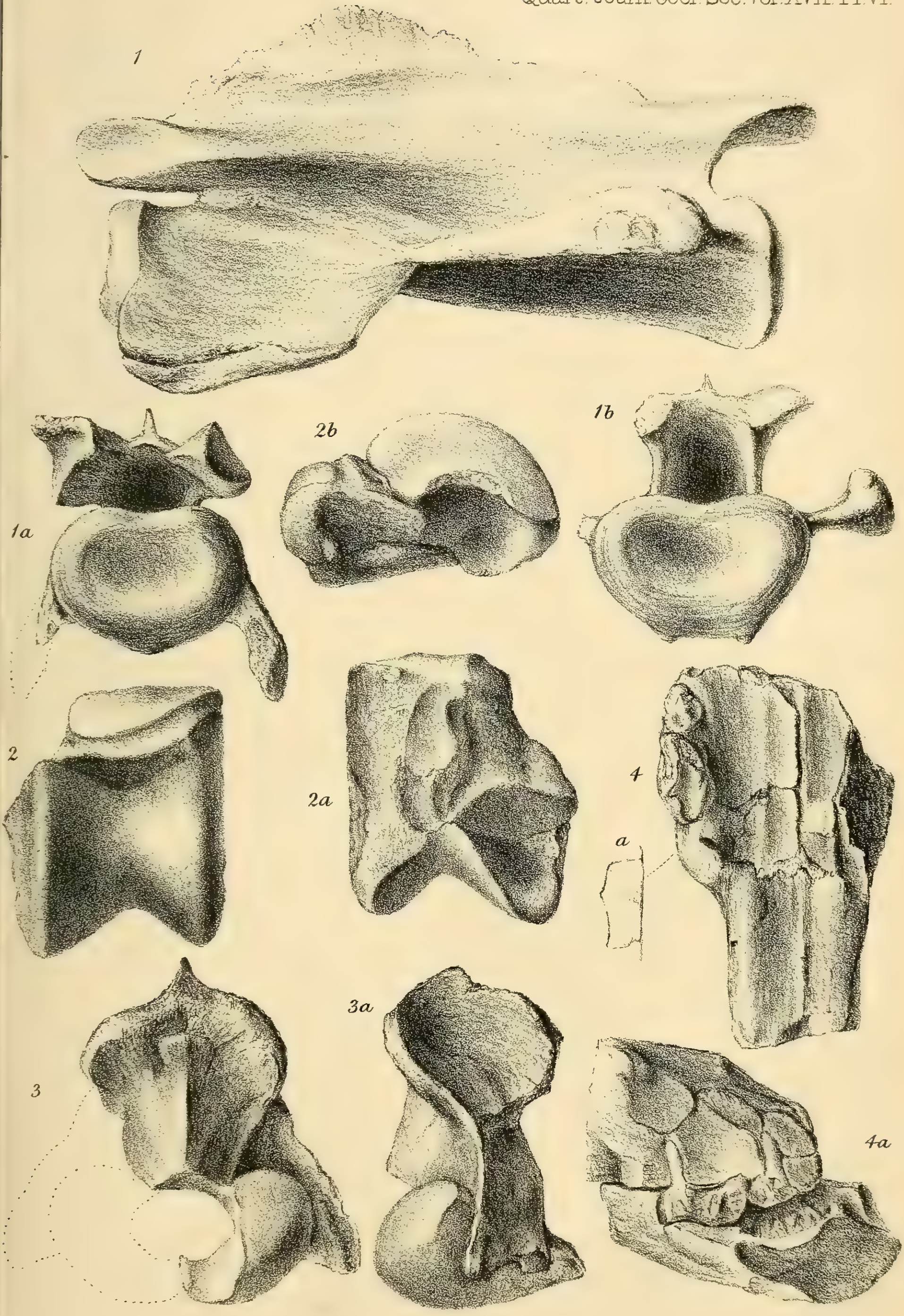
Perissodactyla; and with an astragalus which, in the apparent entire absence of any facet for the cuboid, is, I may affirm, more Perissodactyle than that of any member of the order, except *Hyrax*.

None of the older Tertiary mammalia can produce such strong claims to be considered an example of what has been termed "a generalized type" as *Macrauchenia*; and yet there seems little doubt that the latter is the South American equivalent, in point of age, of our Irish Elk!

Again, *Macrauchenia*, alone, affords a sufficient refutation of the doctrine, that an extinct animal can be safely and certainly restored if we know a single important bone or tooth. If, up to this time, the cervical vertebræ of *Macrauchenia* only had been known, palæontologists would have been justified by all the canons of comparative anatomy in concluding that the rest of its organization was Camelidan. With our present knowledge (leaving *Macrauchenia* aside), a cervical vertebra with elongated centrum, flattened articular ends, an internal vertebral canal, and imperforate transverse processes, as definitely characterizes one of the Camel tribe as the marsupial bones do a Marsupial,—and, indeed, better; for we know of recent non-marsupial animals with marsupial bones. Had, therefore, a block containing an entire skeleton of *Macrauchenia*, but showing only these portions of one of the cervical vertebræ, been placed before an anatomist, he would have been as fully justified in predicting cannon-bones, bi-trochanterian femora, and astragali with two, subequal, scapho-cuboidal facets, as Cuvier was in reasoning from the inflected angle of the jaw to the marsupial bones of his famous Opossum. But, for all that, our hypothetical anatomist would have been wrong; and, instead of finding what he sought, he would have learned a lesson of caution, of great service to his future progress.

EXPLANATION OF PLATE VI.

Fig. 1. Cervical vertebra of *Macrauchenia Boliviensis*, Huxley; restored from the opposite side, posteriorly.
- 1 *a*. The same vertebra, viewed from in front.
- 1 *b*. The same vertebra, viewed from behind.
- 2. Astragalus (left), from above.
- 2 *a*. " " from below.
- 2 *b*. " " from the outer side.
- 3. Fragment of the occipital portion of the cranium, restored in outline.
- 3 *a*. The same fragment, viewed from without and laterally.
- 4. Part of the upper jaw and palate, and lateral view (*a*) of the crown of the most perfect tooth.
- 4 *a*. Side-view of the large fragment of the matrix containing the teeth, with the smaller fragment, exhibiting the coronal impressions, adapted to it.



G. West del. & lith.

W. West imp.

MACRAUCHENIA BOLIVIENSIS.

DECEMBER 5, 1860.

William Salmon, Esq., Ulverstone, Lancashire; Peter Higson, Esq., One of H. M. Inspectors of Coal-mines, Broughton, near Manchester; John Spencer, Esq., Bowood, Wilts; Alexander R. Binnie, Esq., C.E., 7 Upper Lansdowne Terrace; George James Eustace, Esq., Arundel House, Clifton Road, Brighton; F. D. P. Dukinfield Astley, Esq., Dukinfield, Cheshire, Arisaig, W. B., and 67 Eaton Square; and Thomas Baxter, Esq., 1 Castle Place, Worcester, were elected Fellows.

The following communication was read:—

On the STRUCTURE *of the* NORTH-WESTERN HIGHLANDS, *and the* RELATIONS *of the* GNEISS, RED SANDSTONE, *and* QUARTZITE *of* SUTHERLAND *and* ROSS-SHIRE. By JAMES NICOL, F.G.S., F.R.S.E., Professor of Natural History in the University of Aberdeen.

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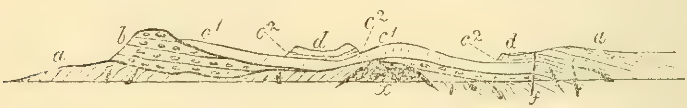
Introduction, and object of paper.
Durine Limestone.
Loch Erriboll Sections.
Overlying Red Sandstone and Quartzite at Tongue.
Loch More Sections.
Lochs Glen Coul and Glen Dhu.
Section of Glasven.
Structure of Assynt and Ben More.
Loch Ailsh Section.
Elphin and Craig-a-Chnockan.
Loch Broom.
Loch Maree and Gairloch.
Loch Torridon and Loch Carron.
South of Skye.
General considerations.
Distribution of the Rocks.
Nature of Formations.
Strike of the Beds.
Mineral character of the Rocks.
Conclusion.

Introduction.—IN a paper read to the Society in 1856, and published in vol. xiii. p. 17–39 of the Geological Journal, I pointed out some of the features of the Gneiss, Red Sandstones, and Quartzites which form such prominent objects in the geology of the north-west of Scotland. I then proved (contrary to the opinion previously entertained) that the Red Sandstone of the North-west Highlands, and especially that of Loch Broom and Applecross, was wholly inferior to the quartzite, which rests on it in an unconformable manner, and spreads out wider to the east. In the same paper I showed that the Assynt and Durness limestone forms the upper member of this series, and that the supposed higher quartzite of Ben More is only the same quartzite rising from under the limestone. In regard to the relation of the quartzite to the eastern gneiss, I stated that, though some of the sections appeared to confirm Dr. Macculloch's view that there are in Sutherland two formations of gneiss—an older below the quartzite, and a newer superior to it,—still the presence of intrusive rocks and other marks of disturbance in the sections I had examined rendered this conclusion less certain and satisfactory than might be wished. In order to determine this most important question, affecting the entire geological history and structure of the north of Scotland, I have subsequently visited this region four times, and examined all the principal sections and almost the entire tract of country from the north coast of Sutherland, to Loch Alsh and Skye in the south, and from Caithness on the east to the Lewis on the west. I now propose to lay the results of these investigations before the Society, as confirming or correcting the views given in my former paper. This is the more necessary, as, whilst some of my statements have been controverted, other statements may seem to support conclusions which I now feel assured are erroneous. The wide region over which these observations extend, and the great importance of the questions involved, together with the weight of authority opposed to the views I support, must form my excuse for the length of this paper and the full details given of some sections.

Object of this paper.—As it may render the bearing of the special sections noticed more evident, I may state that there is no difference of opinion in regard to the first part of the series of formations as established in my paper of 1856. All observers now admit that there is only one great formation of Red Sandstone on the north-west coast, resting unconformably on gneiss, and covered, in many cases also unconformably, by quartzite, and this by the fossiliferous limestone of Durness. But the further order is matter of discussion. I regard this limestone, in Durness, Assynt, Loch Broom, and Loch Keeshorn, as the highest member of the older formations in this region (fig. 1).

Fig. 1.—*Diagram-section of Sutherland and Ross.*



d. Limestone. c^2. Fucoid-beds. c^1. Quartzite. *b.* Red Sandstone. *a.* Crystalline schists. *x.* Granulite or syenite. *f.* Fault.

On the other hand, it has been affirmed* that it is overlain by an upper quartz-rock and limestone, and that these are in turn "clearly and conformably covered," or "followed symmetrically upwards, by mica-schists, flagstones, and a younger gneiss." This paper is designed to prove that no such clear, conformable, or symmetrical upward succession is to be found, but that the line of junction, where this conformable succession is said to occur, is clearly a line of fault, everywhere indicated by proofs of fracture, contortion of the strata, and powerful igneous action†.

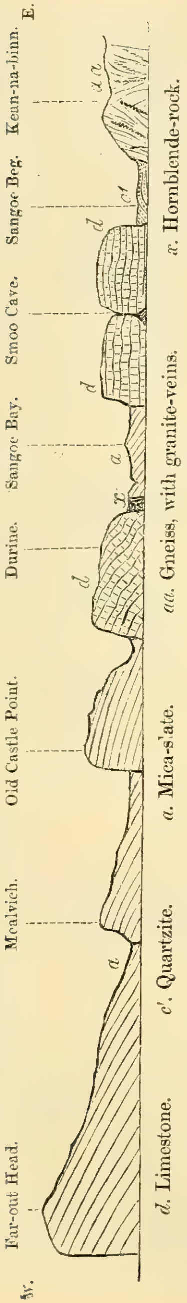
Durine Limestone.—Beginning our sections in the north, the first is that of the Durine limestone. The section given in my former paper‡, though showing the true general relations of the beds, must be cor-

* Sir R. I. Murchison, 'Siluria' (3rd edition), p. 553. See also Murchison "On the Succession of the Older Rocks in the Northernmost Counties of Scotland," Quart. Journ. Geol. Soc. vol. xv. p. 352, and "Supplemental Observations," *ib.* vol. xvi. p. 215, &c.

† The diagram fig. 1, compared with the similar section fig. 2 in p. 217 of vol. xvi. of Quart. Journ. Geol. Soc., will bring out this difference of views more clearly.

‡ Quart. Journ. Geol. Soc. vol. xiii. p. 23. fig. 5.

Fig. 2.—*Section of the Durine District.*



rected as to details by that now given* (fig. 2). Beginning at the western extremity, the magnificent promontory of Far-out Head, 315 feet high, consists from top to bottom of fine-grained white or light-coloured mica-slate, in thin even beds. The dip is from 20° to 25°, or rarely 35°, to E. 35° S. at the Head; but near Old Castle Point, where the rock is also darker in colour, always to the north of east (E. 25°–35° N.). From the regular dip of the beds, the thickness of this mass of mica-slate must be above 2000 feet if the section is unbroken, and not less than 1000 feet if a fault occurs between Far-out Head and Old Castle Point. In mineral character it is quite identical with the mica-slate on the east of the quartzite at Erriboll, and with the mica-slate of Melness on the Kyle of Tongue. It has on this account been said to overlie the Durine limestone; but, after repeated careful examination of the sections, which are most clearly exhibited on the coast, I have been unable to detect the smallest trace of limestone below the mica-slate, or of mica-slate above the limestone. It seems impossible to believe that a mass of mica-slate, at least 1000 feet thick, could have been so thoroughly swept away from the surface of the limestone-field for many miles in extent, had it ever existed above it.

Near Balnakeil and Sangoe Bay the mica-slate appears to dip under the limestone; but, as shown in the section, it is cut off from it by a fault. This limestone forms a great contorted mass, 128 feet high, and is in many parts a red-coloured breccia; but it dips on the whole to the S.E. The brecciated structure is due to a mass of hornblende-rock or serpentine which rises up in Sangoe Bay, bringing with it portions of altered quartzite and mica-slate. The igneous and metamorphic rocks extend south to Loch Calladale, and have evidently been forced up through

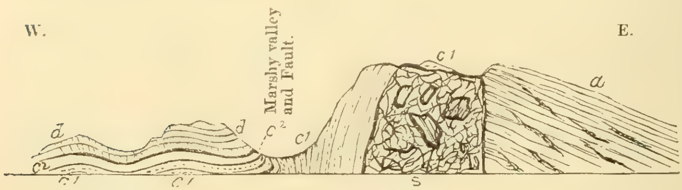
* The sections in the following paper run generally from west to east, and, for more ready comparison, are all drawn as seen from the south. The directions in this paper are also true, having been corrected for the magnetic variation, which in Sutherland is about 29° W.

the limestone, which is broken and contorted near them. The limestone again forms the coast, intersected, however, by another N. and S. line of fault at the Smoo Cave. Near Sangoe Beg the quartzite appears, forming a small wedge-shaped fragment, and is represented by Mr. Cunningham, who first figured the section, as dipping conformably under the limestone*. This is no doubt its normal position; but in this place the rocks are separated by a fault and crush, which has broken up the quartzite into an incoherent breccia. Beyond Cnoc Garrow the quartzite is succeeded by the ridge of gneiss dividing the vale of the Dionard from Loch Erriboll. The ridge runs S.S.W., but the strike of the beds is nearer N.W. (N. 48° W.), and the dip at 70° to 85°, to S.W. or N.E. It is everywhere penetrated by veins and masses of red granite and hornblende-rock, and has evidently been tilted up on the west side since the deposition of the quartzite, which rests in a thin and often-interrupted layer on its eastern side, sloping down to Loch Erriboll †. Small fragments of quartzite also occur on its seaward extremity.

This section of the Durine district is important, as proving that the limestone is the highest formation in the series, and is nowhere covered by higher quartzite or mica-slate; these rocks, where found in the centre of the section, being evidently brought up from below, and thus underlying, not overlying, the limestone. It also shows that the whole district is broken up by faults running from N.N.E. to S.S.W., and that the masses of strata have generally been tilted up on the west.

Sections on Loch Erriboll.—These facts serve to explain the more complex sections on the east side of Loch Erriboll. The first of these (fig. 3) runs from near Camas-an-duin, in an east-by-south direction,

Fig. 3.—*Section of Camas-an-duin, Loch Erriboll.*



d. Limestone. c^2. Fucoid-beds. c^1. Quartzite.
a. Mica- and talc-slates. *s.* Granulite, with fragments of slate.

across the ridge to Loch Hope. On the shore south of Camas Bay, the strata are seen in their regular normal order: first the quartzite (c^1) in curved beds, but dipping on the whole to W.; then (c^2) the fucoid-beds, and above all the limestone (d), in broken irregular strata, but also with a westerly dip. The limestone forms a low hill, sepa-

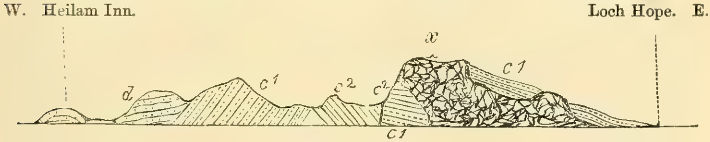
* Cunningham, Geognostical Account of Sutherland in Prize Essays of the Highland Society, vol. xiii. (1839) p. 97, and plate 7. fig. 4. This quartzite does not appear in my former section, which runs further south than it extends.

† Far too great thickness is assigned to this part of the quartzite in my old section, Quart. Journ. Geol. Soc. vol. xiii. p. 23. fig. 4c.

rated from the main ridge by a low marshy valley, indicating a line of fault. This fault is also proved by the quartzite, with its characteristic annelid-tubes (*Pipe-rock*), dipping first 78°, to E. 30° S., and then 70°, to W. 10° N. On the main ridge the same quartzite forms a great curved face of rock, dipping at 50°–65°, to W. 33° N., and higher up 74°, to W. 25° N. The top of the ridge consists of a granitoid igneous rock or granulite *, in part overlain by quartzite. This mass or vein varies from a few yards to above a fourth of a mile in width. Beyond it, on the east side of the ridge, mica- and talc-slates occur in thin regular beds, and often identical in character with the rocks of Far-out Head. The prevailing dip is 15° to 25°, to S. 30° E., but varies considerably near the granulite, where the beds become contorted and interlaced with igneous matter. In a deep valley to the north, a more complete section of the interior of the hill is seen; the granulite widening out to half a mile or more, throwing off the strata on each side, and involving large fragments of the mica-slate, with the laminæ turned in various directions. As these fragments of mica-slate are found in the mass of the igneous rock where it rises up below the quartzite, and, of necessity, have been derived from a still deeper formation, they prove indisputably that the mica-slate is the lower and older rock, and therefore cannot normally overlie the quartzite.

Further north, the igneous rock widens out greatly in Arnaboll Hill, and has produced some remarkable changes on the strata. Thus, on Camas Bay, in the continuation of the fault in the former section, the quartzite dips at 53°, to S. 64° E., and apparently below the igneous mass of the hill. But the openings of the annelid-tubes, and the ripple-marks, which are regularly found on the upper surface of the beds, are here on the lower faces, showing that there has been a complete reversal of the strata. Still proceed-

Fig. 4.—*Section of Drium-an-tenigh, Loch Erriboll.*



d. Limestone. c^2. Fucoid-beds. c^1. Quartzite.
x. Granulite (termed "gneiss" by Mr. Cunningham).

ing northwards we come to the remarkable section of Drium-an-tenigh (fig. 4), described and figured by Mr. Cunningham as an

* It is difficult to assign a name to this rock. In general it is a mixture of compact felspar and quartz, often with an imperfect laminar texture. With these, hornblende or talc or scales of bronzite become occasionally intermixed. But in other places it passes into a distinct crystalline binary granite of orthoclase and quartz, or into felspar-porphyry or diorite, and where in contact with limestone into a kind of serpentine. With all this diversity it exhibits a community of character, more easily recognized than described, along the whole line from Whiten Head to the Sound of Sleat. I have often used the term *granulite*, as the most generally applicable.

example of gneiss conformably overlying the limestone and quartzite. It might be sufficient to state that the rock which he describes as gneiss is the intrusive granulite-rock of the last section*; but, as illustrating the structure of the country, some further details are necessary.

At Heilam Inn, on Loch Erriboll (fig. 4), the limestone dipping 10°–20°, to S. or S.E., but in broken flexured beds, forms both the peninsula and the hill on the mainland to about the line of the road. The next ridge consists of the quartzite, dipping on the west side at 65°, to W. 10° N., and on the east of the ridge 44°, to W. 5° S. Crossing a small valley, the quartzite is again seen, dipping 83°, W. 10° N., and further on the fucoid-beds, dipping 64°, to S. 45° E. The rocks are hidden for about 100 yards by grass and detritus; but at the foot of the cliff the same beds crop out, dipping in one place at 20°, to E. 35° S., and in another at 6°, to S. 10° W. As already stated, these beds are covered, not by gneiss, as in Mr. Cunningham's figure, but by the granulite or eruptive rock forming the great mass of the hill. It has clearly broken through the strata, resting in one place on the fucoid-beds, in another on the quartzite, and further east, towards Loch Hope, is overlain by quartzose beds dipping 25°, to E. 30° S.

The relations of the rocks in this section are quite clear and consistent. No overlying gneiss is seen in it, and the mica-slate is separated from the quartzite by the whole igneous mass of Ben Arnaboll. The quartzite is, however, thrown east as far as Loch Hope; and the junction is then formed partly by the lake, partly by the River Hope to its mouth. In the hills north-east of Hope Ferry there is another outburst of igneous rock, here felspar-porphyry; and at Whiten Head it again appears in great force in the line of junction, intruding partly on the quartzite, but chiefly on the old slates to the east. In this trackless region the sections are best seen in sailing along the coast; but one single fact is decisive of the true relation of the mica-slate and quartzite series. North of Loch Hope Ferry the fucoid-beds and limestone entirely disappear, and only the lower part of the series, or the quartzite, comes in contact with the eastern gneiss or mica-slate. This is the necessary result of the beds along the line of fault having been more exposed to denudation in the north, during the gradual elevation of the land, from the wide and stormy northern ocean, but is quite inexplicable on the hypothesis of conformable upward succession. It has indeed been asserted that this is not the quartzite below the limestone, but another quartzite above it. That this is not the case is, however, proved by the quartzite near

* See Cunningham, Geog. of Sutherland, p. 99, and plate 8. fig. 2. Though a very acute observer and well acquainted with rocks, Mr. Cunningham has in this and some other instances been misled by the strong Wernerian views on the origin of certain rocks which he entertained. In consequence of this bias he entirely mistook the nature of these igneous rocks, which were altogether overlooked until I drew attention to them in the summer of 1859. This is also true of the similar rock on Loch More. Compare Note, p. 94.

Loch Craggy passing below the limestone of Heilam Hill; by the same quartzite again rising up from below the limestone on the coast near Tor-a-vu; and by the fucoid-beds and limestone overlying it in regular order in several places south of the road to Loch Hope Ferry. The occurrence of an upper quartzite in this place is thus not merely without proof, but contrary to many clear sections, and, we shall soon find, has no support in any other locality*.

The junction of the quartzite and mica-slate in the hills south of our first section towards the head of Loch Erriboll equally proves that the mica-slate is the lower formation. In this place the igneous rock has generally thinned out, or rather, instead of being concentrated in a single mass or vein, becomes intermixed with the lower mica- and talc-slates in innumerable fine threads or lines. So intimate is this mixture, that, in many places, it is difficult to say whether the rock should be classed as igneous or stratified. Occasionally, however, larger masses occur, as near the road from Erriboll to Ault-na-harrow, where it forms a boss 50 to 100 yards in diameter, and in the picturesque rock of Craig-na-feolin. Whether concentrated in mass or dispersed in threads, the igneous matter is far more abundant in the lower schists than in the quartzite, the thick hard beds of the latter having apparently resisted its upward progress and thus caused it to spread out in the inferior formation. This distribution, therefore, of the igneous rock is another proof that the eastern mica-slates are the lower formation, as, on the supposition that the quartzite was the lower formation, it ought to have been more powerfully invaded by the igneous rocks than the schists resting upon it †.

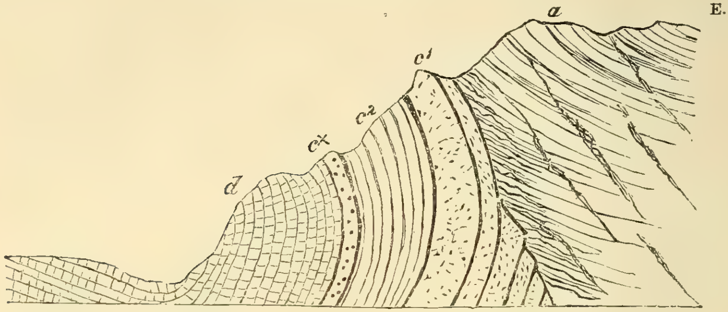
This intrusion of igneous matter, swelling out and expanding the lower schists along the line of fault, has produced some complexity in the sections. In many places the quartzites and mica-slate dip approximately in the same direction, but are separated by a fault, frequently marked by a low marshy hollow. A more interesting section is seen in a small stream above Erriboll House (fig. 5). The upper part of the ridge consists of talcose mica-slates (a) interlaced with lines of red felspar. The dip near the top is 50°–60°, to E.

* This hypothesis of an upper quartzite requires not merely the repetition of the so-called "lower" quartzite with its characteristic annelid-tubes and peculiar mineral characters, but also of a second group of fucoid-beds and a second limestone, identical in order and character with those below! But if such upper beds exist, they ought then to have appeared in the Whiten Head sections, and their absence is thus fatal to the notion of "conformable upward succession" in this region.

† "These strata (chloritic, talcose, and micaceous schists), whatever may be their mineral character, are riddled by the intrusive rock, and in parts much hardened and altered."—Murchison, North Highlands, Quart. Geol. Journ. vol. xvi. p. 235. In p. 233 Sir R. I. Murchison describes them as "interwoven with the metamorphic Lower Silurian strata," *i. e.* with the eastern gneiss; and also affirms that "the granitic felstones and syenites so largely developed in the eastern parts of Assynt . . . . rarely, if ever, occur between the limestones and the upper quartz, but chiefly either in the latter or in the younger or overlying flagstones" (p. 233). That is, according to my view, the igneous rocks are most abundant *in the crystalline schists below*, and *in the quartzite where in contact with them.*

30° N., but below decreases to 15° or 20°, and the beds are broken and irregular. Lower down, the burn tumbles over a thick mass of

Fig. 5.—*Section near Erriboll House.*



d. Limestone. c^2. Fucoid-beds.
c^x. Quartzite. c^1. Quartzite.
a. Mica- and talc-slate, with granitoid veins.

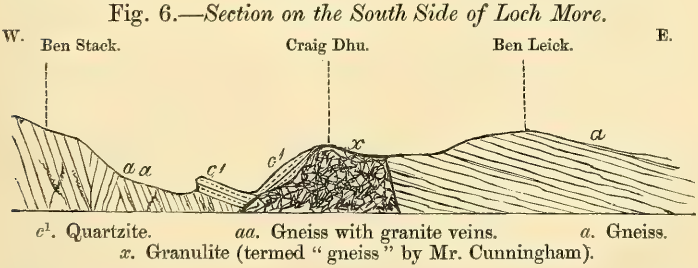
quartzite, very indistinctly stratified, but apparently dipping at 66°, to S. 10° E., and resting on the red fucoid-beds (c^2) dipping at 50°, to E. 20°–30° N. Below them is a bed of hard reddish quartzite (c^x) dipping 35°, to E. 20° S.; and further down the common dark bluish-grey limestone, much fissured and contorted, but with a dip of about 68°, to E. 30° S. The limestone appears to form all the under part of the hill and the low ground to the loch. In this place the quartzite appears to rest on the limestone and dip below the mica-slate, but the succession of the groups shows clearly that this is the result of an upheaval and inversion of the strata. The regular order in the whole north-west of Scotland, from Durness to Loch Keeshorn, is quartzite (c^1), fucoid-beds (c^2), and limestone (d); and we must either admit this inversion, or make the improbable assumption that the succession of the deposits has been completely reversed in the space of a few hundred yards, and only in this very limited zone along the declivity of this ridge.

The same relation of the beds is seen near the Ault-na-harrow road, though, from the more powerful intrusion of the igneous rock, the strata are more irregular in dip and more highly contorted near the line of junction. The quartzite is so compact as to resemble calcedony, and shows no marks of bedding. The fucoid-beds and limestone are in some places nearly vertical, in others more horizontal. The fine-grained talcose mica-slates also, which near the quartzite and intrusive rock dip at 35° and 30°, to E. 60° S., further east dip at 10° or 5°, to E. or E. 15° S. Over the hill, towards Loch Hope, the dip becomes even lower, so that the undulations of the strata cause them in many places to dip to the west.

Overlying Red Sandstone and Quartzite of Tongue.—Another proof of the true succession of the formations in the north of Sutherland appears in the vicinity of Tongue, about eight or ten miles to the east of the sections just described. On the east side of the Kyle of Tongue several remarkable masses of red conglomerate rest on the gneiss. These have hitherto been allowed to remain in the Old Red or Devonian formation, though separated from the nearest undoubted Old Red strata, on the east of Strathie, by an interval of eighteen miles. This summer (1860) I examined these conglomerates, in the expectation that they might throw some light on the history of this western region. They consist of rounded or angular fragments of coarse- or fine-grained gneiss, mica-slate, granite, felspar-porphyry, and vein-quartz; but I could find no trace of the red sandstone, quartzite, or limestone, which now form the great ranges of mountains in the west. This entire absence of any fragments of these rocks, which have formerly covered to the depth of some thousand feet a tract of country forty or fifty miles wide and more than a hundred miles long, and not ten miles distant, seems altogether inexplicable on the supposition that the two deposits are of widely different age—the one Cambrian and Lower Silurian, the other Old Red or Devonian. The conclusion seems therefore irresistible that these Tongue conglomerates are identical in age, as they are in mineral character and composition, with the red conglomerates and sandstones of the west coast. This identity is confirmed by the occurrence of the overlying quartzite on Cnoc Craggie, near Loch Laoghal. The greater part of the hill consists of the conglomerate overlain on the south side by the quartzite in thick irregular beds. The preservation of these interesting fragments seems due to the great syenite-eruption of Ben Laoghal, which has at once hardened the beds and preserved them from removal by denudation. In this place, therefore, there is clear evidence that so far from underlying all the gneiss of central Sutherland, the red sandstone and quartzite of the west are again found resting upon it ten miles to the east of the supposed overlap.

Loch More Section.—The next point to the south where the quartzite is said to be overlain conformably by gneiss is near the north-west end of Loch More. In Mr. Cunningham's section this relation of the rocks is very distinct; but on the ground the phenomena are quite opposed to this view, as shown by the section fig. 6, the result of a

Fig. 6.—*Section on the South Side of Loch More.*



c^1. Quartzite. *aa.* Gneiss with granite veins. *a.* Gneiss.
x. Granulite (termed "gneiss" by Mr. Cunningham).

careful examination of the locality in two separate seasons. At the western extremity of Loch More, the quartzite (c^1) rests in a long bold cliff on the gneiss (*a*), which forms Ben Stack and the mountainous region to the west coast. Beyond the Lodge, granulite like that on Loch Erriboll breaks up through the quartzite, and may be traced for more than a mile along the upper part of the mountain, where it is free from the detritus that covers the slopes near the road and loch. Mr. Cunningham represents this rock as gneiss*; but it is truly unstratified, and its intrusive character is shown by the quartzite having been pushed up and resting on it in broken and nearly vertical beds, dipping 85°, to N. 40° W. Higher up the lake this igneous rock meets the gneiss of Ben Leick, exposed in lofty vertical cliffs, and dipping first 20°, to E. 75° N., and then 15°, to E. 30° N. On the south side of the ridge, towards Strathna-carrian, the gneiss, full of igneous veins and greatly contorted, has quite the aspect of the gneiss round Loch Inver and Scourie, but dips at 40°, to E. 20° S. It seems merely the continuation of the beds seen in the west part of the section, in Ben Stack. That there is in this place no conformable upward succession from quartzite to gneiss is proved not merely by the clear break in the section, but even more by the quartzite, which, on the north side of Loch Stack and Loch More, has a thickness of 800 to 1000 feet, as well seen in the front of Arkle and Foinaven,—on the south side of these lakes disappearing, except a few fragments not the tenth part of that thickness. This is the necessary result of denudation over a line of fault; whereas no amount of denudation could ever show less than the full thickness of the deposits in any section of conformable strata. As shown in the figure, I have been unable to detect any trace of quartzite or limestone on the east side of the intrusive rock.

Lochs Glen Coul and Glen Dhu, and Glasven.—The quartzite, with the same degraded dimensions, ranges across to Lochs Glen Dhu and Glen Coul†, and in the rugged mountains that surround the inner recesses of these noble sea-lochs is said to be again overlain by gneiss. This, however, is a mere optical deception, caused by the rocks being seen from the low ground or the sea; as the quartzite, though dipping eastwards, only abuts on the rounded knolls that rise up behind, and is generally separated from them by a low marshy valley. The rock too, described as conformably overlying gneiss, is in some places an intrusive syenite, in others true granitic gneiss, but rising up in nearly vertical masses with a strike at right angles to the beds on which it has been said to rest. This

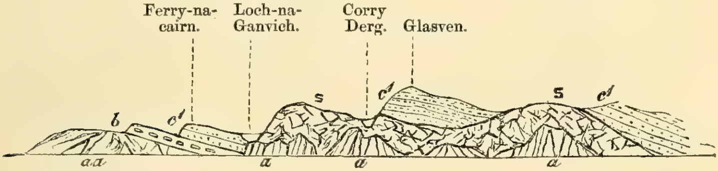
* It seems to be the rock thus described: "Another prominent variety [of gneiss] exists in a rock almost entirely composed of compact felspar and quartz, arranged, not in distinct concretions, but, on the contrary, so closely connected that their linear position can only be detected after atmospherical agents have partially abraded the felspar. This remarkable gneiss forms some hills on the south side of Loch More."—Cunningham, Geog. of Sutherland, p. 77.

† In the geological map published in No. 62 of the Quart. Journ. Geol. Soc. (May 1860), a broad band of "upper quartz-rock" is laid down in this region. It is rather remarkable that these same rocks, now described as quartz-rock, were quoted as a true overlying gneiss both by Macculloch and Cunningham. As stated in the text, the rock is gneiss (but not overlying) or a syenite.

is well seen on the south side of Loch Glen Coul, where the quartzite, which, only one or two miles south, expands into the great mountain-group of Assynt, has been denuded almost to a single bed.

The section (fig. 7) of the northern side of Glasven shows the true structure very clearly. The low hills on the west, near Kyle

Fig. 7.—*Section of Glasven.*



c^1. Quartzite. *b*. Red sandstone. *a*. Granitic gneiss.
aa. Gneiss with hornblende. *s*. Syenite.

Sku Ferry and Unapool, consist of gneiss and hornblende-rocks, the strata often at very low angles (dip 12° N. 15° E). They are covered by red sandstone, stretching south, in a broad terraced valley, up into the corries of Queenaig. This valley is bordered on the south-east by a precipitous cliff of quartzite, formed by a great sheet of rock, which, sloping down from the summit of Queenaig, folds over on the south to Loch Assynt, on the north to Loch Glen Coul. The quartzite is well seen on the west side of Loch-na-Ganvich, where the burn from the lake has almost cut through the cliff in a deep ravine, and forms a picturesque waterfall within a few yards of its exit*. The quartzite dips at 10°, to S. 53° E., apparently below the ridge of Glasven, hitherto represented as entirely consisting of quartzite. The east side of the lake, however, I found was syenite, intermixed with nearly vertical masses of granitic gneiss running N. 10°–15° W. This rock forms the whole north side of Glasven as far back as the tarn of the Corry Derg. The high bare cliffs on the south-east of this small lake exhibit a beautiful section. The northern extremity consists of the syenite, overlain on the south by undulating beds of quartzite†. This rock forms the summit and southern slopes of Glasven; but the syenite passes below and reappears on the other side of the mountain. I have again found it in the inner corries of Ben Uarran and Ben More; so that it probably forms the axis of the whole range of mountains. From the Corry Derg it extends north to Cnoc-na-Craig-Ganvich and the head of Loch Glen Coul, where

* We have here, therefore, a miniature of the phenomena of Niagara and the American lakes. The erosive action has only to proceed a few yards further in order to drain the lake; but from the extreme hardness of the quartzite this may require a very long period.—See Sir C. Lyell's Travels in North America, vol. i. pp. 29–46.

† The little tarn is shut in on the north-west by moraines or glacier-mounds. These on the north, opposite the syenite cliff, are entirely composed of syenite boulders; on the south, where the cliff is quartzite, of quartzite boulders, with a mixed group between.

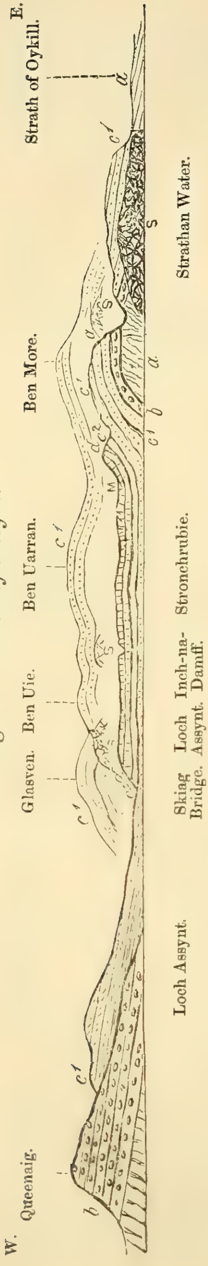


Fig. 8.—*Section of Assynt.*

d. Limestone. c^1. Quartzite. *a*. Gneiss. (The gneiss of Queenaig has granitic and syenitic veins.) *s*. Syenite.
c^2. Fucoid-beds. *b*. Red sandstone. M. Loch Maolack Corry.

the granitic gneiss intermixed with syenite-veins is seen stretching away to the east, below the quartzite-beds of Ben Uie and Ben Uarran, and continuous with the gneiss of central Sutherland. Nothing can be more striking than the contrast between the dark-grey gneiss and hornblende-rocks forming the north-east base of these mountains and the almost horizontal beds of brilliant white quartzite, which rest upon them for miles.

Assynt.—The structure of the Assynt region is represented in the next section (fig. 8), extending from Queenaig on the west to the south-east declivities of Ben More. The middle of the section shows the strata as seen on the north shore of Loch Assynt and in Stronchrubie; but in the background I have sketched-in the northern range of mountains connecting Queenaig and Ben More, showing the continuity of the quartzite round the whole limestone-plateau.

The first formation, on the west, is the gneiss (*a*) intermixed with veins of granite and syenite. It is covered by red sandstone (*b*), beautifully seen in the western declivities of Queenaig, and this by the quartzite (c^1) sloping down from the summit of the mountain in vast, almost unbroken sheets. As well seen in Skiag Burn, the dip is about 10°, and thus probably unconformable to the red sandstone below, though the great faults intersecting the mountains and the protrusion of igneous rocks render this fact less certain than I formerly thought. Above it come the fucoid-beds (c^2), and over them the limestone (*d*), forming the whole low ground north of Loch Assynt, from Skiag Bridge by Stronchrubie to the foot of the Ben More mountains. This limestone is the highest bed in the series, being everywhere troughed by the quartzite. As this fact is of great importance, and as it has been affirmed that an upper quartzite and limestone occur in this region, a few confirmatory facts and sections must be noticed.

In ascending the road from Skiag Bridge towards Kyle Sku, the fucoid-beds and limestone may be seen resting on the quartzite, almost to the summit of the ridge. Before reaching the foot of Glasven, however, they thin out, and the quartzite of that mountain and of Queenaig form one continuous mass, as shown in the section. That the quartzite of Glasven does not overlie the limestone is further proved by no trace of limestone being seen in the Corry Derg (fig. 7, p. 95), where the syenite brings up the bottom beds, or between the quartzite and gneiss in the noble sections exposed on the north-east side of that mountain, formerly described.

The same thing is shown by the section from Loch Assynt near the School-house, in a N.N.E. direction across Cnoc-an-drein. Close to the lake the quartzite is seen cropping out below the limestone, which forms all the declivity of the hill, and dips to E. 25° to 30° N., at angles ranging from 20° to 40° or more. This diversity of dip is caused by the intrusion among the strata of irregular veins, or lenticular-shaped masses of trap, of which I enumerated not fewer than eight or ten. Near the top of the ridge the quartzite appears to rest on the limestone, but is separated from it by veins of green trap and of dark clove-brown felspar-porphyry. The quartzite (*Pipe-rock*) dips first E. at 25° to 35°, and then higher up on Cnoc-an-drein rises to 75° to 80°, at length becoming vertical, with a N.N.W. strike, having clearly been forced up by the intrusion of the syenite (shown at *s* in figs. 7 & 8).

The inferiority of the quartzite to the limestone is even more clearly seen in the Poulan-drein Burn, at the south-east end of Cnoc-an-drein; it may also be seen along the whole valley of the Traligill River, almost to the Bealach at the foot of Ben More. Everywhere the limestone, which in the plateau of Stronchrubie on the south side of the stream dips towards these mountains, is found to form a synclinal axis, and on the north side to dip away from the quartzite. The only obscurity in the sections arises from the synclinal fold in the limestone being conjoined with a great fault in the quartzite, which is thus brought up in enormous crushed masses, so broken that the lines of stratification can hardly be detected*: this is especially seen near the foot of Coniveal; but in no place have I observed the limestone dipping below the quartzite of these mountains.

In the line of the section no such obscurity exists. Immediately to the east of Loch Maolack-Corry, well known for its Gillaroo trout, the Stronchrubie limestone, continuous throughout, rises up into a hill, and is seen very distinctly dipping at 40°, to W. 40° N., in

* This peculiar combination of faults with synclinals (or what may be named a "faulted-synclinal") is very common in Sutherland. It has probably been caused by the refractory nature of the quartzite, which was more easily broken than bent. To the same cause we may ascribe the frequent combination of a crush (or broken and brecciated condition of the rock) with one or both of these faults and synclinals.

slightly undulating beds. On the east side of this hill the limestone rests on the red shales or fucoid-beds (c^2), and these in turn on the quartzite (c^1), dipping at 20°, to W. 40° N., and rising in great curved beds to the top of the next hill. The section is so clear, and the correspondence of the deposits so exact, that there can be no doubt that this is the east side of the Queenaig synclinal. Still stronger evidence of this fact may be obtained by tracing the quartzite along the shore of Loch Assynt and up the Stronchrubie valley*, everywhere dipping below the limestone, till it turns round its southern extremity and rises up into Brebag. From this mountain the quartzite may be followed along the bare ledges of rock north to Ben More, and thence, as shown in the section, round till it again joins that of Queenaig.

A more interesting confirmation of this peculiar structure of the Assynt district (the highest of its formations, filling the bottom of the valley) is furnished by the drainage of its waters. Almost all the streams from the lofty north-eastern mountains, from Brebag, Ben More, and Ben Uarran, on reaching the synclinal line in the limestone, fall into swallow-holes and disappear for a considerable space. The whole moor is dotted over with round pits, some dry, some filled with water at the bottom, through which the drainage is effected. In some places deserted river-beds, only occupied by the water in rainy seasons, are seen; in other places the subterranean torrent is heard rolling along at the bottom of a deep dark cave. Now all this underground drainage is directed towards Loch Assynt, the centre of the synclinal, proving that the strata dip to this point, and not north or east below Ben More or Brebag. The water descends through the limestone to the quartzite, and is again thrown out on the surface by this impervious stratum, often in very copious springs†.

There is thus, in this place, no "upper quartz-rock" resting on the Stronchrubie and Assynt limestone, and the hills referred to this newer formation clearly consist of the quartzite below the limestone, brought up over an anticlinal. Singularly enough, too, some of these so-called "upper" or "newer quartz-rocks" are even an *older* formation than the lower quartzite. When examining Canisp and Queenaig, I was struck by the peculiar aspect of some of the hills on the eastern side of Stronchrubie, usually classed as quartzite. From their reddish colour I thought that they probably consisted of felspar-porphyry, like that of Loch Borrolan; but on examination I found that they were formed of red sandstone, identical in character with

* In my former paper (Quart. Journ. Geol. Soc. vol. xiii. p. 25) I stated that the Stronchrubie limestone and the underlying quartzite had "probably been brought up by a fault." Several faults in the line of that section are well seen in the face of the Stronchrubie cliff; but, as shown in the present section, the limestone and quartzite are brought up rather by undulations in the beds and the general rise of the synclinal than by these faults. Compare Quart. Journ. Geol. Soc. vol. xvi. p. 221 (note ‡).

† I estimated the flow of the "Remarkable Spring" above Stronchrubie at 7000 gallons per minute, after some weeks of dry weather.

that of Queenaig and Suilven. In the corries of Ben More similar beds occur, resting on gneiss or mica-slate (as shown in the section); and there can be no doubt that this is the true western Red Sandstone ("*Cambrian*" of Murchison) brought up in the centre of the so-called "upper quartz-rock," and that the synclinal is thus complete in all the formations from the upper limestone to the lowest gneiss.

The eastern extremity of the section shows the true structure of Ben More, as exposed in the wild corries round the Dhu Loch More. Granitic gneiss and mica-slate, with intrusive igneous rocks, form the nucleus of the mountain, throwing off the quartzite all around, as from a great centre of elevation. Further west an enormous mass of beautiful binary granite rises into a group of rugged mountains, quite unlike the quartzite with which they have hitherto been confounded*. Taken in connexion with the Loch Borrolan porphyry, with which it is probably continuous, this granite must produce most powerful disturbance along the south-east border of the quartzite; and we can easily understand how observers who ignored or overlooked its existence should mistake the true relations of the stratified rocks it has affected†.

Loch Ailsh Section.—It is, again, affirmed that in the vicinity of Loch Ailsh and the higher part of Strath Oykill, the "upper quartz-rock" forming the Assynt mountains "is overlain by a second zone of limestone," and both "conformably surmounted by upper micaceous, chloritic, gneissose, flaggy strata . . . for several miles across the strata‡." My examination of the locality last summer (1860) by no means confirms these views. The "upper quartz-rock" is simply the continuation of the quartzite of Brebag and Canisp, and the "second zone of limestone" merely the repetition, in a denuded form, on the other side of the anticlinal, of the limestone of Stronchrubie and Assynt. Any slight change in the colour or character of the strata is readily accounted for by the intrusion of the red porphyry of Loch Borrolan, which probably at no great depth underlies the rocks shown in the section (fig. 9).

This section begins on the west, at Cnoc Chaorinie, with a hard reddish or clove-brown hornstone-porphyry (x) with distinct crystals of felspar, but probably only a semifused mass of the quartzite.

* In justice to Mr. Cunningham, it must be stated that the greater portion of these granite mountains lie in Ross-shire, and thus beyond the limits of his map.

† In the Quart. Journ. Geol. Soc. vol. xvi. p. 232, it is stated that "no igneous rock has yet been observed to be associated with the lower quartz-rock of Assynt;" and that the "large crystalled porphyry" of Canisp may be considered "for the present to be characteristic of the Cambrian age in the North-western Highlands." In 1859, I found that this very beautiful porphyry not only breaks though the quartzite of Canisp, but forms a mass more than a mile in diameter in the same "lower quartz-rock," within a few hundred yards of the inn of Inchna-Damff. It is thus of later date than either the Red Sandstone or Quartzite, and is one of those powerful agents affecting the relations of these and the other strata which have hitherto been overlooked.

‡ Sir R. I. Murchison, "Supplemental Observations on the North of Scotland," Quart. Journ. Geol. Soc. vol. xvi. p. 223.

It passes up into great masses of red hornstone or hardened quartzite (c^1) mixed with fragments of limestone, and dipping very irregularly at about 20°, to E. 10° N. A true quartzite succeeds, dipping

Fig. 9.—*Section near Loch Ailsh.*

c^1. Quartzite. c^2. Fucoid-beds. a. Chlorite-slate and gneiss.
x, p^1, p^2. Porphyries.

at 25°, to E. 10° S., and overlain by irregular masses of red limestone. Red felspar-porphyry (p^1) follows, then quartzite, dipping at 35°, and then the fucoid or slaty beds (c^2) intercalated with red limestone and quartzite, and dipping at 43° to 30°, to E. Passing over a low ridge, the next beds seen are hardened quartzite, dipping at 50°, to E. 20° S. A small stream descending from the hill marks a line of fault; and beyond it beds of chlorite-slate, beautifully contorted, and resembling marbled paper on the cross-fracture, occur. A second vein of red felspar-porphyry (p^2) follows, and then fine-grained quartzose gneiss, dipping first 20°, to E., and then 40°, to E. 40° S. From this point to Alt-Ellag (a distance of half a mile), the rocks are fine-grained slaty gneiss in undulating beds, but the dip gradually falling to 23°, 18°, and 16° at the Bridge. The same fine-grained, micaceous, undulating gneiss continues down Strath Oykill to Rosehall, but in all the lower part of the valley, beyond the influence of the porphyry and granite on the west, has a persistent N.W. strike and S.W. dip (dip 45°–50°, to S. 15°–25° W.*).

The facts just stated leave little doubt as to the true relations of the beds in this section. The only obscurity arises from the strata being much concealed by soil and grass, and only visible at intervals where they crop out on the surface, and, from the repeated intrusion of igneous masses, modifying the usual aspect of the rocks. The lower part of the section is evidently the quartzite hardened and altered by contact with igneous rocks: the centre is no less plainly the fucoid-beds, intermixed with some thin beds of red limestone and quartzite. Over these, had the series been complete, the dark-blue or grey limestone ought to have appeared, but is wanting in this place; then follows the gneiss, probably crushed out of its dominant north-west strike in the lower Strath Oykill by the intrusion of the western porphyry and granite. The remarkable change in the dip on both sides of the line of junction proves the existence of a fault; but the absence of the limestone is specially fatal to the opinion that there is here "conformable upward succession." This absence is the more remarkable from its occurrence in full strength at Elphin to the south, and also on Loch Ailsh to the north. I followed the limestone along this north line till it was cut out by the

* See also the dips on Cunningham's map.

granite, but I could find no place where it is seen to dip below the gneiss. Even in the deep ravines of the Alt-na-Caillich, close to the line of junction, where the eastern gneiss is exposed for a thickness of some hundred feet, I could discover no limestone below it. This is the more remarkable as, from the enormous protrusion of igneous rocks on the west, some such anomalous features might have been expected to occur*.

Elphin and Craig-a-Chnockan.—Having now noticed all the sections adduced in proof of the eastern gneiss overlying the limestone and quartzite, I shall pass more rapidly over some others in the southward extension of the line of fracture, though not less interesting and instructive. To the south of Loch Borrolan and the Strath Oykill road the country is flat and obscured by moss and drift, but the limestone and quartzite appear to be thrown west to the east end of Loch Urigill. The whole eastern anticlinal of Ben More and Brebag has in this region been swept away, and the line of junction is in the continuation of the synclinal passing through the Gillaroo Loch. So extensive has been the denudation of the overlying quartzite and limestone that the gneiss is almost continuous from west to east. True granitic gneiss with syenite-veins is seen very distinctly at the east end of the Camaloch, whilst, according to Mr. Cunningham, gneiss also extends from the upper part of Loch Urigill into the Cromalt Hills.

Round Elphin the limestone is very well seen, resting, as usual, on the fucoid-beds and quartzite (dip 12°–15°, to E. or E. 10° S.). These beds are very fully exposed for some miles, and their relation to the eastern gneiss clearly shown in the precipitous cliff of Craig-a-Chnockan, below which the Ullapool road passes. The section

Fig. 10.—*Section on the Ullapool Road, near Elphin.*

d. Limestone. *c*². Fucoid-beds. *c*¹. Quartzite. *b*. Red sandstone. *a*. Gneiss. *x*. Granitic vein.

fig. 10 shows the structure of this place. In the west, Coulmore consists of the Red Sandstone. The valley below is quartzite, extending up to the cliff of Craig-a-Chnockan. In the line of section it dips 12°–15°, to E. 40° S., and is covered by the limestone. Further east the limestone rises up and thins out, and the quartzite comes

* The section fig. 5 (p. 223 in Quart. Journ. Geol. Soc. vol. xvi.), though said to occur to the east of Alt-Ellag (where I am not aware that any quartzite or limestone is to be found), probably refers to this locality; but I could observe no place where the beds rest connectedly on each other as there represented. Even in it, however, the sequence is broken by "hornstone-porphyry;" and the "*gneissose limestone*" is perhaps also an intrusive rock. The absence, too, of the fucoid-beds and limestone in their normal form is opposed to any regular upward succession in that section.

to the surface, followed (still to the east) by fine-grained gneiss, much curved and contorted, but dipping at 35° to 50°, to S. 5° W. In this line a thin vein of granite or syenite, like that on Loch Erriboll, intervenes. Further south, on the Ullapool road, the line of junction intersects the front of the vertical cliff, and the strata are well exposed. The quartzite, dipping at 5° or 6°, and covered by the fucoid-beds and limestone, comes within a few yards of the gneiss. A thick, strong bed of the quartzite then dips down at 12°, as if below the gneiss, whilst the thinner fucoid-beds above are curved and fractured and the limestone broken suddenly off. The dark-coloured, thin-bedded gneiss dips at 20°, and is traversed by innumerable fissures, filled with thin lines of the granitic rock, running up the face of the cliff, from which, a little to the south, a large mass of trap protrudes. Had the strata been less clearly exposed, the gneiss might have been supposed to overlie the quartzite; but the fracture and contortion of the beds, seen even in hand-specimens, and particularly the manner in which the limestone and fucoid-beds are cut out, prove that there is, in this place, not "conformable upward succession," but a line of fault with powerful lateral compression.

Loch Broom.—The next point to the south where the rocks are well seen is the vicinity of Loch Broom, described in my former paper*. As there stated, the quartzite is cut off from the gneiss by a thick bed of intrusive rock, in some places a felspar-porphyry, in others near the limestone inclining to serpentine, but generally identical in character with the rocks in the same position in the previous sections. This summer (1860) I again visited Loch Broom, but saw little to add to my former memoir, except that the porphyry or igneous rock is more extensive than represented in the sections, and, rising up in a wider mass below, separates the eastern gneiss more strongly from the quartzite. I must also call attention to the fact, exhibited in the sections, that, whilst on the north shore the series of the quartzite group is complete, on the south side of Loch Broom the limestone above has been entirely cut out.

Loch Maree and Gairloch.—In my former paper I described some sections in the vicinity of the Gairloch and Loch Maree. I have since examined the mountains round the upper portion of that most beautiful lake, and the line of junction between the quartzite and gneiss with some care; and the section (fig. 11, p. 104) shows the facts as seen on the north side of the loch. In the west there is, first, the red sandstone (*b*), dipping west at a low angle, as seen near Pol Ewe and the Gairloch. Then follows the gneiss, as formerly stated, often a fine-grained grey rock with intercalated beds of mica-slate, in Ben Lair, with hornblende-strata. Near the head of the loch the red sandstone cone of Sleugach rises above a basis of gneiss, forming one of the grandest mountains in this truly mountain-region. The gneiss, generally red or grey and highly crystalline, where seen below the red sandstone dipped 70°–80°, to W. 20° S., and hence has

* Quart. Journ. Geol. Soc. vol. xiii. (1856) p. 18–24 and figs. 1 & 2.

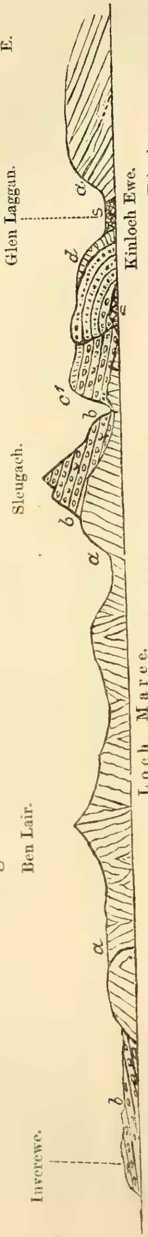
a N.W. strike. Where it meets the red sandstone the surface is very rugged and uneven, and the beds above are often, as noticed on the Gairloch, a coarse angular breccia. The red sandstone dips 15°, to S. 33° E. In the mountain, east of Sleugach, and separated from it by a deep ravine, the red sandstone is covered by the quartzite, which continues along the summit of the ridge to Glen Laggan. The red sandstone, however, forms the foot of the hill to the head of the loch; but further up a great mass of igneous rock (*s*) (a fine-grained syenite, or rather diorite) forms the base of the hill, covered by broken masses of quartzite and limestone. In the valley of the Laggan the limestone (*d*) has been quarried in several places, dipping to E. 20° S., but much altered by the diorite (*s*), which forms a wide mass, running for several miles along the valley. The other side of the valley consists of grey granitic gneiss (*a*), in some places more quartzose, in others fine-grained and micaceous, and dipping 15°–30°, to E. 30°–40° S. In the low ground, however, near the mouth of the glen, grey granitic gneiss occurs, dipping at 60°–70°, to E. 45° N., and thus with a true N.W. strike, though on the east side of the fault and of the quartzite*. In this place, though the formations are only separated by a deep and narrow valley, yet the quartzite is nowhere seen dipping below the gneiss on the east, nor the gneiss resting on the quartzite on the west.

In the low ground near Kinloch Ewe, the gneiss is seen in the bed of the river near the inn, dipping 10° to S. 45° E., and about a quarter of a mile west the red sandstone forms some low rounded knolls. The intervening space is thickly covered by detritus; but, from the dip of the beds, the red sandstone here is probably in contact with the eastern gneiss, the limestone and quartzite having been entirely denuded. The quartzite, sloping down from Ben Éy, covers the red sandstone on the south, but at the foot of Loch Clair is again thrown out, so that the eastern gneiss and red sandstone are brought into contact. The same relation also appears to occur in the wild country towards Loch Carron. Anyhow we find in this region that the limestone, forming the upper portion of the quartzite series, only occurs in rare fragments, where left behind in the denuding process, so that the phenomena are quite opposed to any theory of continuous upward succession.

In regard to the relation of the quartzite and red sandstone in this region, they seem to be generally conformable to each other. I infer this, rather from the view of the two formations as exposed in the mural precipices of the mountains, than from direct observation on the beds. This general parallelism is very marked in Leagach, one of the loftiest mountains on the west coast, and, as the appearance is the same whether the hill is looked at from the north or south, can hardly be a mere optical effect. In Ben Ey (a mountain nearly as high, but more picturesque), the same parallelism appears, and is the more striking from both the red sandstone and quartzite

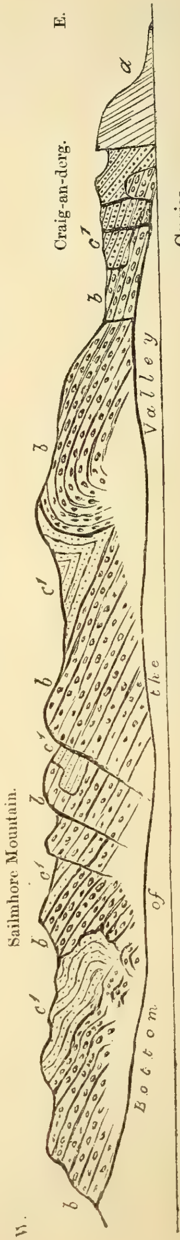
* It may thus be regarded as the other side of the anticlinal to the beds seen under the red sandstone of Sleugach.

Fig. 11.—*Section on the North Side of Loch Maree.*



d. Limestone. c¹. Quartzite. b. Red sandstone. a. Gneiss. s. Diorite.

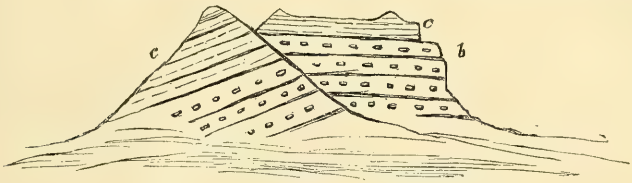
Fig. 13.—*Section in the Loch Torridon and Loch Carron country.*



c¹. Quartzite. b. Red sandstone. a. Gneiss.

having been tilted over towards the line of fault on the east, as shown in the sketch* fig. 12.

Fig. 12.—*Section of Ben Ey and Leagach.* Seen from the north.



c. Quartzite. *b.* Red sandstone.

Loch Torridon and Loch Carron.—Immediately south of Loch Maree and the Gairloch lies the wild unfrequented district of Loch Torridon. On the shores of this most magnificent sea-loch, and in the lofty mountains that surround it on every side, there is some of the grandest scenery in Scotland, and at the same time some of the most instructive geological sections. The whole structure of the mountains is clearly exposed in the naked precipitous walls of rock, built up, layer above layer, in the most majestic piles of masonry. How geologists could traverse this region, and yet believe that the great Red Sandstone formation of Applecross and the West Highlands was superior to the quartzite, is hard to understand; and yet this was regarded as an established fact up to the publication of my paper on the N.W. Highlands in 1856.

The lowest formation is, as usual, the gneiss, well seen on the narrows near Sheildag, where its dip is N.E., and commonly at a considerable angle. It rises to a height of 2000 to 3000 feet in Ben Ailigin and the Gairloch mountains, but is in most places hidden by the red sandstone. On the lower loch the red sandstone generally dips west at 8° or 10°, but often higher near the outer headlands. In many places it seems almost horizontal, as in the lofty mountain of Leagach, where it is covered apparently in conformable superposition by the white quartzite. On the upper Loch Torridon the dip changes to the east, and then retains this direction throughout. As shown in the section (fig. 13) of the mountains east of Loch Torridon, it is still overlain by the quartzite. In this most remarkable section, the red sandstone, always dipping to the east, and covered by its capping of quartzite, is again and again brought up by faults; and this not only on the summits of distinct mountains, but no less than five times in a single continuous ridge. Had only a surface-view been exposed, as each fragment of quartzite seems to dip below the next one of red sandstone, it might have been supposed that the rocks alternated with each other; but no such mistake can be made in this place, as the true structure of the mountain, to a depth of some hundred feet, is clearly exhibited in the vertical escarp-

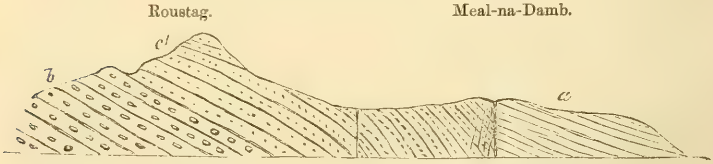
* This rough sketch, taken from the plateau on the north, shows only about half the true elevation.

ments of the mountain, and repeated with equal distinctness in the corresponding precipices on the other side of the valley. It is impossible to give verbal details; but the figure, imperfect as it unavoidably is, represents the facts more distinctly than words. It is clear that the quartzite is mere fragments of the upper formation, brought down repeatedly by faults, and in some cases even forced in below the inferior red sandstone by enormous lateral pressure. This very clear natural section thus tells us the structure of the N.W. Highlands, and the true nature of those apparently anomalous sections which have puzzled observers in other parts of the line of junction.

The most critical point of the section is at the eastern extremity, where the red sandstone and quartzite meet the gneiss or, rather, mica-slate. Near this point the quartzite, still resting on red sandstone, is thrown down some hundred feet below its former level. Repeated slips take place, still further depressing the quartzite and red sandstone, the latter dipping at about 15°, until near the line of junction, where both the quartzite and sandstone dip at 33°, to S. 55° E. An irregular, but nearly vertical, line of fault here separates them from the mica-slate, dipping on the whole at 40° or 50°, to S. or S.E., but in some parts ranging from 15° to 60°, and dipping in various directions from N.E. to S.W. It forms but a mere coating, as it were, on the front of the hill, and is in part intermixed with compact syenitic rocks, which may explain the irregularity in the dip and direction of the beds. In this place, therefore, there is no overlap of the gneiss on the quartzite, but the two formations meet, end to end, along a line of fracture. It is also noteworthy that in this section the red sandstone does not thin-out before the quartzite, as in some of the northern localities, but comes up almost into contact with the gneiss.

Another section in the hills between Loch Carron and Loch Keeshorn (fig. 14) exhibits the same relation even more clearly. In this

Fig. 14.—*Section near Loch Carron.*



c^1. Quartzite. *b.* Red sandstone.
a. Talcose or chloritic schist, with granitoid veins.

place the quartzite, resting on the red sandstone, rises into some lofty mountains. Near the line of junction it dips at 50° to 60°, to E. 20° S., but is fractured and broken, and small fragments of the limestone are involved between it and the talc or chlorite-slate. This rock is much intermixed with veins of red granitoid matter, and dips very irregularly at angles of 20° to 30°, to E. 15° to 45° S., but in part at low angles nearly north. A small stream, running down the side of the hill, along the line of junction, has fully exposed the connexion of the two rocks, but in no place could I find the talc-slate resting on the quartzite. Had the beds been continued in the dip, so as to pass below the slate, this could scarcely have failed to be visible.

In my former paper there is a section of the Loch Keeshorn limestone*. I have since examined the district more carefully than I was then able to do. I have now ascertained that the limestone rests on the quartzite, which in one place dips at 15°, to S. 40° E. The limestone is, as usual, more broken and irregular, but near the bridge to Applecross it dips at 64°, to E. 8° N. The talc-slates on the east have a dip of 20°, to E. 30° N.; and, on the whole, lower angles than those given in my former paper seem to prevail in these beds. Granulite and hornblende-rocks, however, abound near the line of junction; and I was still unsuccessful in finding any point where the talc- or mica-slates overlap the limestone or quartzite. I have now no doubt, from the facts seen at the junction in other places, that the limestone and talc-slate are divided by a line of fault. The occurrence of the limestone in this position, though quite analogous to what is seen in Assynt, is very important. It lies in a low valley at the foot of the red sandstone hills of Applecross, more than 2000 feet high, and, as its regular position is above the quartzite, it must have been thrown down from fully 3000 feet. It must at one time also have been far more widely distributed; fragments of it, some only a few feet or yards in diameter, being found in many places, let in (as it were) along the line of junction of the quartzite and crystalline schists. There is thus evidence of a most enormous amount both of disturbance and denudation in this region; and also proof that, where the quartzite meets the talc-slates or gneiss, without the intervention of the limestone, whatever may be their apparent relations, there cannot possibly be a true conformable upward succession.

South of Skye.—The section of the southern part of Skye given in my former paper (fig. 7, p. 31) offers similar proof that the red sandstone does not dip under, but rests unconformably on, the eastern gneiss, and this gneiss dipping S.E., and identical in mineral character with that of the mainland. The red sandstone dips W.N.W., and is clearly continuous with that of Applecross and the North-west. The section is so clear and decisive that I can do nothing more than refer to the description in my former paper†.

General Considerations.

The sections now noticed, at short intervals along the whole line of junction from north to south, seem quite decisive of the true relations of the quartzite and eastern gneiss. They have not been selected as more favourable to my own views than others that might

* Quart. Journ. Geol. Soc. vol. xiii. p. 29. fig. 6.

† Quart. Journ. Geol. Soc. vol. xiii. p. 31. In the sketch-map in vol. xv. pl. 12, this underlying gneiss is coloured and lettered the same as the so-called overlying gneiss in Sutherland.

have been chosen, but are those brought forward as the proofs on which the opposite theory is founded; yet in not one of them have we found that regular continuous upward succession which this theory requires, but in every one of them irruptions of igneous intrusive rocks, and other indications of faults and disturbance, depriving them of all weight as evidence of regular order. Here, therefore, I might have left the question, satisfied with this appeal to special sections; but there are a few more general facts, leading to the same conclusion, which require a short notice. In order to perceive the full force of these facts as bearing on the present question, it must ever be kept in mind that this region has undergone a most enormous amount of denudation—strata of at least 2000 to 3000 feet in thickness having in some places been swept away from the surface; consequently, if there be here a line of conformable overlap, all the beds that dip east (the so-called "upper gneiss," the limestone, and quartzite) must have originally extended much further to the west.

First. The mode of distribution of the rocks is altogether inconsistent with the hypothesis that the eastern gneiss overlies the red sandstone or quartzite. The red sandstone, with a width from east to west of thirty to fifty miles, is seen in innumerable places—at Stornoway, Cape Wrath, Assynt, Gairloch, Skye, resting for miles in all directions on the gneiss. So also the quartzite, with a breadth of ten or twelve miles, is everywhere clearly seen to rest on the red sandstone. Mile after mile, from north to south and east to west, from mountain-top to mountain-top, from valley to valley, this relation may be traced. And thus also it is with the limestone, though this formation is now of such limited dimensions. In every locality where it occurs—Durness, Erriboll, Loch More, Assynt, Ullapool, Loch Maree, Loch Keeshorn, it is seen resting on the quartzite. This relation can be traced round and round isolated masses of the limestone, and across synclinal basins of miles in extent. But how does it stand with the next step in the series, the so-called "upper gneiss" or mica-slate? This gneiss extends for fifty or a hundred miles to the east, and, we are told, conformably overlies the quartzite or the limestone, for a hundred miles from north to south; and for what distance to the east or west of the line of junction has this overlap been observed? Nowhere for more than a few feet, or yards, at one or two widely separated intervals, has this overlap ever been even alledged to occur. We seek in vain for any isolated portion of mica-slate resting on quartzite or limestone, on the west of this line of supposed overlap; and it is as fruitless to ask which of the thousands of lofty gneiss-mountains on the east reposes on a basis of these so-called older rocks. Such a thorough diversity in this step in the series from all those that precede, and from all the known relations of overlying beds in other countries, proves that here no such overlap takes place.

Second. The diversity in the strata brought into contact with the eastern gneiss proves that the line of junction is along a fault, and not one of conformable upward succession. Where a series of beds rest conformably on each other, no amount of denudation can ever alter their order, or cut out one or two members of the series; but along a line of fault the case is just the reverse: always, as denudation proceeds, older and older beds will be brought to the surface, and thus into contact with the gneiss. This will be readily understood from the diagram fig. 1. As drawn, the limestone *d* is shown in contact with the eastern gneiss *a*. A small amount of denudation would bring first the fucoid-beds c^2, then the quartzite c^1, the red sandstone *b*, and even the western gneiss, into contact with the eastern gneiss. On the other hand, in the contrasted section (fig. 2, p. 217) in vol. xvi. of the Journal of the Society, it is evident that no amount of denudation could ever bring the gneissic flagstones d^2 on the east into contact with the lower limestones c^2 or quartzite c^1, and still less with the Cambrian sandstone *b*. But my sections show (and the fact cannot be disputed) that in some places the limestone, in others (and more often) the quartzite, in others the red sandstone, thus come into contact with the gneiss. As a marked instance, I may refer to Loch Maree, where, in less than a couple of miles, all these relations may be seen, as denudation has been more or less extensive. In the hill on one side of the valley it is limestone, in the low ground in the centre the red sandstone, and then, on the other side, the quartzite. How "conformable upward succession" can explain such relations I cannot comprehend.

Third. That there is here a line of fault, and not of conformable overlap, is proved by the nature of the formations. Though along the line of fault, and especially where the disturbance has been most violent, the quartzite is often much hardened and semifused, still it is a decidedly fragmentary, granular rock. The gneiss or mica-slates, said to rest on it, are no less distinctly crystalline in structure. This is true even of the finest-grained of these strata. Now, before we can accept the theory of superposition, this fact must be explained. That a truly crystalline metamorphic rock should rest on deposits, thousands of feet thick, of unaltered sandstones and limestones with fossils, is so improbable, so contrary to all the established principles of geology, that nothing but the most undoubted evidence and the failure of all other methods of explanation would justify us in admitting the fact. In the Alps, where such superposition of crystalline on unaltered strata is seen, the most distinguished and experienced geologists have found it "necessary to admit that the strata had been inverted, not by frequent folds . . . . but in one enormous overthrow, so that over the wide horizontal area, the uppermost strata, which might have been lying in troughs or depressions due to some grand early plication, were covered by the lateral extrusion over them of older and more crystalline masses*."

* Sir R. I. Murchison, "On the Structure of the Alps, &c.," Quart. Geol. Journ. vol. v. p. 248. I need hardly say that no locality is known to me in Scotland where the crystalline strata overlie the limestone or quartzite in the clear manner shown in the section (fig. 28, p. 246) to which the above extract refers. The phenomena in some parts of Sutherland are more closely represented by fig. 4, p. 182, fig. 16, p. 203, and fig. 19, p. 209, of the same valuable and instructive memoir.

A comparatively very small amount of inversion and extrusion of older crystalline masses will suffice to explain any of the Scottish sections, even as drawn and described by the advocates of an overlying "younger gneiss." That such inversion and extrusion of older masses on younger (though not of gneiss on quartzite) do occur in this region of Scotland, and close to this line of fault, is shown in the section of Sailmhore (fig. 13, p. 104); and, until some rational theory is produced of the mode in which an overlying formation, hundreds of square miles in extent and thousands of feet in thickness, can have been metamorphosed, whilst the underlying formation, of equal thickness and scarcely less in extent, has escaped, we shall be justified in admitting inversions and extrusion equal to those in the Alps.

Strike of the beds.—Two general facts have been adduced in proof of the diversity of age of the gneiss on the west coast of Sutherland and that forming the interior of the country—the diversity in strike and in mineral character. Now it is evident that the relative age of the gneiss in these two regions is an entirely different question from the question whether or not the eastern gneiss overlies the quartzite. I have more than once stated that the gneiss of Scotland probably belongs in part to distinct geological periods, and have specially pointed out "the great tract of gneiss with associated quartzite and limestone, stretching from Aberdeenshire through Perthshire to the Breadalbane Highlands of Argyleshire, as a newer formation*." And such newer beds might also occur in Sutherland and yet not overlie the quartzite. In regard to the strike of the gneiss, I mentioned in my former paper that in the western region "its general direction was to the N.W.," whereas, as Macculloch had long before stated, in the centre of the country it was more commonly "to the south-eastward †." But this distinction is not universal. The mica-slate of Far-out Head dips to the S.E.; and, as Mr. Cunningham shows, the gneiss round Canisp and Suilven has also a N.E. strike, and a similar strike with S.E. dip is common in the south of the Lewis. On the other hand, a N.W. strike prevails in Strath Oykill and the lower part of Loch Shin, and in Ross-shire similar diversity occurs. This sudden and entire change in the strike of the rocks in different parts of the Highlands is, however, a very marked feature, and is clearly connected with that peculiarity of structure exhibited by the previous sections. The country does not consist of one large mass of strata, but of fragments, irregular in form and of more or less extent, and each subject to its own laws of position. They may be well compared to the shoals of ice seen on a river-bank in spring, each turned in its own direction, with little reference to the fragments beside it.

There can be no doubt, however, that the country has undergone a very general disturbance subsequent to the deposition of the

* Note explanatory of the Geol. Map of Scotland, pp. 2, 3; and the Section engraved on the Map. See also "On the Slate Rocks of Easdale, &c.," Quart. Journ. Geol. Soc. vol. xv. p. 110.

† Quart. Journ. Geol. Soc. vol. xiii. pp. 35, 37.

quartzite, throwing it over in large fragments to the S.E., independent altogether of the present strike or dip of the beds. This is clearly shown on the west side of Loch Erriboll, where the quartzite, with the inferior gneiss-plateau on which it rests, have both a dip to the S.E. This is also true of the great plateau of gneiss on which we must suppose the quartzite of Foinaven and Arkle, now dipping at 20° to the S.E., to have been laid down in nearly horizontal masses. So also on Loch Maree and Loch Carron, there is evidence of the upturn of the formations in enormous fragments. Further east, the same overthrow of the masses from the N.W. is evident in the form of the hills and in the position of the newer formations of the east coast. The cause of this most remarkable convulsion must be sought in some more powerful agent than any of the masses of igneous rocks now visible on the surface in this part of Scotland.

Mineral character.—The diversity in the mineralogical character of the rocks has also been often alleged in proof of the overlap of the eastern gneiss. Now it must be stated that, though Dr. Macculloch coloured the whole of central Sutherland as gneiss, yet Mr. Cunningham recognized that some portions of it were mica-slate; and the same distinction appears in subsequent maps. In comparing the gneiss of the east with that of the west, such mica- and chlorite-slates must of course be set aside, though it is undoubtedly true that they are quite as crystalline in texture, and as distinctly separated from the true sedimentary formations, as the gneiss. In regard to the gneiss itself, Mr. Cunningham, undoubtedly both a competent and an unprejudiced observer, states that "the mineral characters of both" (the eastern gneiss, which he believed to overlie the quartzite, and the western, which underlies it) "are essentially the same*," and expressly affirms that "he has never found any indications of mechanical action on its individual constituent minerals†." It is no doubt true that "hornblendic varieties of gneiss are very characteristic of this formation in the west of Sutherland‡;" but the more usual kinds also occur, and in the Gairloch district its general aspect "is a light or dark grey, finely granular rock, interstratified with beds of mica-slate§." In Far-out Head, again, it is a true mica-slate, identical in mineral character (as it is also in dip and direction) with that on Loch Hope and the Kyle of Tongue. On the other hand, rocks quite as hornblendic and as thoroughly granitic in character are common in the eastern gneiss-district. Such rocks may be seen near Strath Naver, Strathie Point, and on the borders of Caithness in Sutherland; at Auch-na-Sheen and Loch Carron in Ross-shire, and at Glen Elg and Isle Oronsay in Skye in Inverness. Further east, in Banff-, Aberdeen-, and Kincardine-shires, they are perhaps the more common varieties. In truth, this peculiar character of the rock has no relation whatever to its age or locality, but only, it would appear, to its proximity to the

* "Geog. of Sutherland," Trans. of Highland Society, vol. xiii. (1839) p. 101.
† *Ib.* p. 78.
‡ Nicol, "Quartzites of N.W. Scotland," Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 24. § *Ib.* p. 28.

great foci of igneous action. Wherever we find granitic and syenitic eruptions, there the gneiss appears in these more coarsely crystalline and hornblendic forms. Any person who examines the western gneiss carefully will find these varieties prevailing only in places where intrusive granite and syenite rocks abound, as, for instance, near Scourie and Loch Inver, in parts of Lewis and Harris, and on Loch Greinord. And it is these intrusive igneous rocks, or rather the interior masses, of which these veins are the mere external indications, which have expanded, and tilted up the western gneiss, and thus produced that line of fault and compression which I have pointed out in the sections above described. So far, therefore, from furnishing any objection to the theory maintained in this paper, the fact that the western gneiss has been thus powerfully interlaced, swollen out, and modified, by veins and beds of red granite, syenite, and other hornblende-rocks, by furnishing a veritable and sufficient cause for the fracture and disturbance observed along the line of junction, adds one more proof of its truth.

It is often assumed that the fine-grained gneiss, mica-slate, and clay-slate are younger than the coarse-grained gneiss and hornblende-rocks; but on what grounds I have nowhere seen stated. In the Southern Grampians I have shown that the very reverse relation prevails, and that the clay-slates and mica-slates may be seen troughing the central gneiss both on the south-east and north-west. We see this along the great line of fracture intersecting the primary formations, from the Murray Firth to the Linnhe Loch, and still more on the southern margin of the Grampians. This remarkable line of fracture, dividing the Old Red Sandstone from the primary formations, is the exact counterpart of the great line of fracture now shown to exist in the north-west. As in the south, we find it bringing up fine-grained gneiss, mica- or talc-slate, and even clay-slate, succeeded further to the east by coarse-grained and hornblendic gneiss.

Conclusion.

Before concluding, I must state that, even had it been proved that the mica-slate or fine-grained gneiss of Sutherland truly overlaps the quartzite, and that this overlap is the result of subsequent deposition, the fact would not bear out the conclusions that have been deduced from it, or establish that entire revolution in Scottish geology which has been supposed. Proof would still be wanted that the mica-slate of Loch Erriboll and Loch Hope is inferior to the great masses of granitic gneiss in the centre of Sutherland. We might ask for a continuous section through the interminable moors of the Moin, and for evidence that the Kyle of Tongue and the huge syenite domes of Ben Laoghal and Ben Stomino do not break the series and bring up anew the lower and older gneiss. But such continuous sections have never even been attempted, either there or through the wilds of Assynt and Strath Oykill, still less across the mountain-fastnesses of the Dirry Moor and Fannich Forest, so as to assure us that no older underlying gneiss comes up there. Till this is done, there is no evidence to connect the great mass of crystalline schists stretching from the north coast of Sutherland to the south of Inverness-shire more closely with the mica-slates of Ben Hope than with the gneiss of Scourie, Loch Inver, and the Gairloch, or to justify us in throwing aside mineral characters for some assumed synchronism in the age of the original, but now wholly altered, deposits.

No such revolution in Scottish geology is, however, required. The sections, when carefully examined, are clear and simple, and quite analogous to those of other mountain-regions. Every fact and section alleged in proof of the recent origin of the eastern crystalline strata appears on investigation to lead directly to the reverse conclusion. At Durine, the mica-slate of the Bishop's Castle, stated to overlie the limestone, does not show a single calcareous bed in a thickness of 1000 to 2000 feet of strata; and the same mica-slates are forced up from below the limestone, by igneous action, in the very centre of the field. At Whiten Head and Loch Erriboll, the quartzites and limestone, alleged to dip under the gneiss, are in part separated from it by intrusive rocks, or meet it in wholly discordant position, often so inverted and denuded that the upper limestone is entirely cut out before reaching the line of supposed overlap. So too it is on Loch More and Loch Glen Coul, where mere fragments of the quartzite series are left abutting against, not dipping under, the old gneiss, or separated from it by intrusive igneous rocks. In Assynt the so-called "upper quartz-rock" is proved to have no existence, but to be a mere upturn of the old quartzite, which is seen resting on the gneiss for miles along its N.E. margin, and on the S.E. is divided from it by a line of fault with huge intrusive masses of granite and porphyry. Further south, in Cromarty- and Ross-shires, the same phenomena prevail. The newer, overlying strata—whether the limestone, the quartzite, or the Red Sandstone—always overlie or abut against, never dip under, the older eastern gneiss. In Skye, finally, the Red Sandstone, the oldest overlying deposit, dipping N.W., rests on the eastern gneiss dipping S.E., and thus in an entirely discordant position. Such are the facts and sections on which I have no hesitation in asking a verdict in favour of the old, long-established principles of Scottish geology.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

December 19, 1860.

The Rev. William Liston, Bushbury Vicarage, Wolverhampton; the Rev. Alfred Deck, A.M., Royal Military College, Sandhurst; and Charles Rooke, Esq., Bellevue Cottage, Scarborough, were elected Fellows.

The following communications were read:—

1. *On the* Structure *of the* South-West Highlands *of* Scotland. By T. F. Jamieson, Esq.

(Communicated by Sir R. I. Murchison, V.P.G.S. &c.)

Contents.

1. Introduction: general arrangement of the rocks of the district.
2. The anticlinal axis, and character of the strata composing it.
3. Succession of the older rocks in Bute.
4. The geology of Knapdale.
5. The relations of the rocks of Jura, &c., to those described.
6. The greenstones of Knapdale; metamorphic action; metallic veins.
7. Probable age of the rocks described.

§ 1. The following paper is an attempt to throw some light upon the relations of those rocks which figure in our geological maps as the mica-schist, clay-slate, the chlorite-series, and quartz-rock of the South-western Highlands, and the prolongations of which, ranging N.E. through the middle of Scotland, form so conspicuous a feature in the geology of that country.

An examination of these rocks, as displayed in Bute and Argyleshire, has led me to believe that from the quartz-rock of Jura to the border of the Old Red Sandstone we have a conformable series of strata which, although closely linked together, may be classed into three distinct groups, namely:—

1. A set of lower grits, of immense thickness.
2. A great mass of thin-bedded slates.
3. A set of upper grits, with intercalated seams of slate.

Beds of limestone* occur here and there sparingly in all the three divisions, the thickest I have met with being situated deep down in the lower grits. These limestones appear to attain their greatest development in the western extension of the strata, thinning out to the eastward. The siliceous grits also seem to become purer and more devoid of green sediment as we trace them to the west. All the members of the series, namely the upper grits, slates, and lower grits, have a persistent strike from S.W. to N.E. (sometimes in Bute approaching to due N. and S.), following one another in conformable order; and the three groups graduate into each other where they meet, in such a way as to show that they belong to one continuous succession of deposits; and not only so, but the materials of which they are composed seem to have been derived from very similar sources: beds of the lower grit are often undistinguishable in hand-specimens, or even in mass, from those of the upper, being made up chiefly of water-worn grains of quartz, many of which are of a peculiar semitransparent bluish tint.

I selected the region lying between Rothesay and the Sound of Jura as likely to afford the best insight into the disposition of these rocks, and devoted my attention to the districts of Bute, Cowal, Knapdale, and the line of the Crinan Canal†. In order to render the following pages more intelligible, it is necessary, before going further, to mention that the outlines of the chlorite-series, as laid down in the map of Macculloch, and also in the smaller one of Nicol, are incorrect in some places to a considerable degree. For instance, almost all South Knapdale is brought into the chlorite-series, whereas the coast-section across the strike of the beds from Barmore to Inverneil, being a distance of about six miles, shows no chlorite-slate, but is almost all a highly siliceous grit, often forming indeed a true quartz-rock. On both sides of Loch Fyne also, in the neighbourhood of Otter Ferry, and apparently for some distance up and down the

* I ought to mention that I did not myself observe any mass of limestone in the middle division, or great body of slates, although it occurs closely associated with slate amongst the upper grits. See, however, Macculloch, 'Western Isles,' vol. ii. p. 458, where he says that the limestone "peculiarly accompanies" the clay-slate. And Col. Imrie, in the Edinburgh Philosophical Transactions, vol. vi., describing the section along the N. Esk in Kincardineshire, mentions a bed of limestone, 6 feet thick, amongst the slate, and another, 12 feet thick, between two thin layers of black shale. See also an interesting short notice by Prof. James D. Forbes on the geology of the parish of Fordoun, in the 'Statistical Account of Kincardineshire,' where he mentions a bed of limestone occurring in the midst of the slate, and quarried at a place called Clattering-brigs. Daniel Sharpe seems to have found no limestone in the slate at Brig o' Cally, Birnam, Stratherne, and Aberfoyle, nor in the Loch Lomond section, these being the points where he examined it: see his paper in the Quart. Journ. Geol. Soc., vol. viii. p. 126.

† A geological sketch-map of the district has been deposited by the author in the Society's Library.

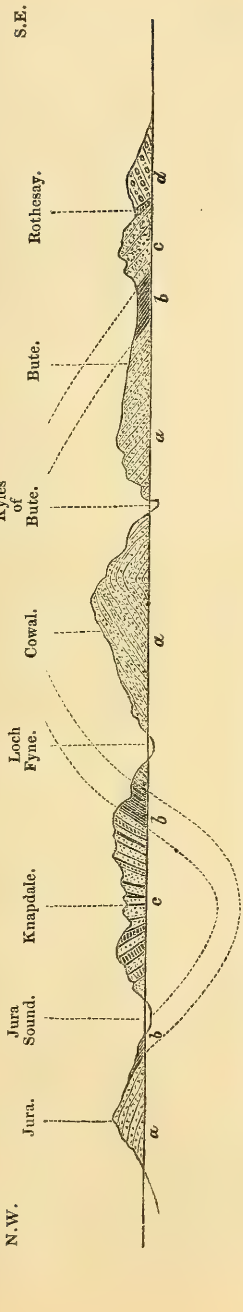

Diagram-section illustrating the supposed disposition of the Rocks from Jura to Rothesay.

d. Old Red Sandstone (and trap-rock at Rothesay).
c. Upper grits (and greenstones in Knapdale).
b. Slates [represented as too thin in Bute].
a. Lower grits.

loch, the strata are also very quartzose with no chlorite-schist; and the thickest and most persistent bed of limestone, lying at the base of this immense quartz-deposit, and ranging from Otter by Barmore to Western Loch Tarbert, is omitted; while the whole district of Knapdale and Crinan is traversed by great ranges of greenstone, of which no indication is given. The reason, however, why Macculloch omitted these greenstones will be afterwards more particularly referred to.

§ 2. The rocks of the district under consideration seem to have been thrown into a great undulation, whose anticlinal axis extends from the north of Cantyre, through Cowal, by the head of Loch Ridun, on to Loch Eck, while the axis of the synclinal trough seems to lie nearly on the line of Loch Swen. (See the woodcut.)

Macculloch, in his work on the Western Isles (vol. ii. p. 288), had remarked that in Cantyre the mica-schist on the eastern shore dips to the E., and on the other side to the W.; and Sir Roderick Murchison (Quart. Journ. Geol. Soc. vol. vii. p. 169) had noticed a fine anticlinal fold at Loch Eck. These observations led me to expect that I should find a similar phenomenon somewhere near the north end of Bute; and accordingly I went in search of it, and found it, not in Bute itself, but a little to the north of that island, in a high ridge near the Tighnabruich steamboat-quay, in the Kyles of Bute. There in the brow of a large hill called Ben Y-Happel, whose height is probably somewhere about 1500 feet, the folding over of the strata is distinctly seen; and from its summit I could trace the same anticlinal axis ranging away for a long distance in a direction about N. 33° E. The lowermost strata brought up in this anticlinal fold, as displayed here and at the north end of Cantyre, where also I examined them, consist of hard rugged masses, much wrinkled and contorted, composed chiefly of quartz and mica—although felspar is also to be found, but forming in most places only a small proportion of the rock. Portions would be correctly termed gneiss, even in the strict definition of that term; other portions are more of the nature of mica-schist, and some of quartz-rock; while a greenish substance, probably chlorite, is often added to the whole, giving its hue to the rock. The colour, however, varies from pale greenish-grey to reddish-brown; and I observed small glancing octahedral crystals of iron-ore in various places, both near the Kyles of Bute and in Cantyre. Notwithstanding the metamorphic aspect of these lower rocks, their original arenaceous character is in many parts still apparent,—thick beds, finely laminated, containing the same water-worn particles of blue and grey quartz as are found throughout the whole series of both upper and lower grits, being met with in various places, enclosed amongst others in which the lines of deposition are confused and obliterated. But the pervading feature of the rocks all about this anticlinal axis is their highly corrugated and contorted aspect, with numerous segregations of quartz. This axis, I am inclined to think, will be found to run through the country for a very long distance, passing probably by the head of Loch Lomond on to the valley of the Tay, where I observed it on the same line of strike, at Aberfeldy, in 1859. Similar masses of hard rugged gneiss and mica-schist rise up there in a gentle dome-shaped curve, and are seen on both sides of the river, more especially in the rocky face of Weem Craig, throwing off heavy micaceous strata to S.E. and N.W.

From this ridge of Ben Y-Happel, if we proceed (south-eastward) across the Kyles through Bute, we pass over a continuous series of rocks, following each other in quite conformable succession, and all dipping steadily to S.E., until we come to the Old Red Sandstone in the neighbourhood of Rothesay. In no part of Bute, neither on the east side nor on the west, where I followed the whole line of coast to the north of Scalpsie Bay, nor in the interior, did I meet with a reversed or N.W. dip. If again we turn our faces in the opposite direction (to the N.W.), towards Loch Fyne, we pass over a similar series, all conformable and dipping in like manner to the N.W.

§ 3. Taking the Bute or south-eastern section first (which is a very satisfactory one, as the rocks are disposed with great regularity, without any quantity of disturbing masses of an eruptive nature), it will be found that after leaving the neighbourhood of the anticlinal axis the strata become gradually less and less contorted, falling into regular parallel beds as we proceed across them; the quantity of mica also becomes less; and the great body of the rocks along the very clear section of the west shore from Kilmichael to Kildavannan Point, where the slates commence (a distance of about three miles), is found to be highly siliceous, often almost wholly of quartz; they are in fact altered sandstones, varying in quality from fine grit to coarse indurated sand with grains of the size of peas or beans, in which the water-worn character still remains quite distinct; nothing, however, so coarse as to be termed a conglomerate occurred. These siliceous beds vary in colour, but are for the most part of a pale greenish-grey. Although no decided beds of slate are met with along this part of the section, yet there are some nests and patches of fine sediment, and even a few thin seams here and there, precisely similar in quality to the material of the thick beds of slate that follow. These slates commence, as I have said, at Kildavannan Point on the west, and at Ardmaleish Point on the east shore of Bute, there being frequent alternations of grit and slate where they first make their appearance. Near the base of these slates at Kildavannan Point I found some arenaceous beds composed of exceedingly fine yellowish-green sand, often parted by seams of white sand, all laminated in the most delicate manner, and even showing indications of false-bedding; they also alternate with coarser-grained layers similar in quality to the underlying grits.

The great mass of slates that follow consists of finely laminated sediments, generally of a greenish colour, but containing also many seams of dark-blue roofing-slate: these blue slates are not exclusively confined to any one part of the series, being found in every portion of this division; but they are perhaps most frequent near the base and top. Many alternations of dark-blue and green slate are seen. I am led to notice this the more as the late Daniel Sharpe, in his paper on the Southern Border of the Highlands (Quart. Journ. Geol. Soc. vol. viii. p. 127), had distinguished them into two separate formations, which he termed the dark-blue and the chloritic or green slates,—a distinction perhaps correctly descriptive of some localities, but evidently not of general application. These thin-bedded sediments form a zone across Bute, extending on the west side from Kildavannan Point to a place called Mecknoch, a short distance to the north of Ardscalpsie Point, and on the east side from Ardmaleish Point to Rothesay Bay. They vary in quality from the finest clay-slate to slaty flag and thin-bedded grit; and there are even a few seams of coarse-grained grit, with grains of the size of peas or beans. Intercalated seams of mica-slate are also met with. The colour is various, from dark purplish-blue to pale green, silvery-grey, and brown; but the prevailing hue is greenish, and the rock is thinly laminated. They had been the finely comminuted sediment, the silty mud and clay, of the old sea-bottom, the grits being the sand and gravel. So far as I noticed, the lines of deposition are almost always quite distinct, being seldom obscured by cleavage.

Covering these thin-bedded slates I found a thick mass of grit, forming a rugged hilly ridge stretching from Ardscalpsie Point to Barone Park near Rothesay, and of which Barone Hill attains a height of 538 feet. These grits cover a space at least a mile broad in the middle of the island; and as they dip at high angles to the S.E., they must evidently be of considerable thickness. They are the uppermost of the old rocks as displayed in Bute, being bordered by the Old Red Sandstone to the south along the hollow of Loch Fadd and Loch Quien to Scalpsie Bay. The actual meeting of the two formations, however, is not seen, except for an insignificant space at Ardscalpsie Point; and a good deal of trap appears to occur along the boundary. These grits are not, I believe, the lower grits brought up by a fault; for they follow the slates quite conformably, without, so far as I observed, any trap coming up between them. They contain at least one band of dark-blue slate, near their base, and also differ somewhat from the lower grits in containing a greater prevalence of coarse-grained gravelly layers. There may be some fault at the N.E. base of Barone Hill, where the ridge suddenly terminates; for a great trap-dyke crosses the island there in a N.W. direction, and, traversing the slates, runs out to the shore a little to the south of Ettrick Bay; but whether there actually is a fault I could not determine, owing to the nature of the ground.

This Bute section, then, shows at its base a set of contorted micaceous grits, followed by a great thickness of siliceous grit, above which comes an extensive development of thin-bedded sediments or slates, these slates being covered by a mass of grit containing at least one seam of slate, and having more frequent beds of coarse gravelly texture than are met with in the lower grits. I observed no decided bed of limestone in these old rocks of Bute, but found, deep down in the lower grit, some beds which contained calcareous matter, effervescing readily with nitric acid.

§ 4. In descending from the anticlinal axis of Ben Y-Happel towards Loch Fyne, I found ridge after ridge unfolding precisely the same series of micaceous grits, indurated sand, and gravel that I had examined in Bute, in a similar state of metamorphism, all following each other conformably, and dipping steadily to the N.W.; and these grits continue all the way across to Otter, where there is a thick bed of bluish limestone, forming a small wooded hill, and quarried beside the Otter Inn. This limestone is covered by quartz-rock, and rests upon micaceous grit, and may be traced for some distance along its N.E. strike. I believe it is also found near Kilfinnan; and I heard of some other seams or bands of limestone in Cowal—one somewhere near Ardlamont Point, which would be on the strike of the calcareous grit that I observed in Bute.

Again, in following the west shore of Loch Fyne from the neighbourhood of the anticlinal axis in Cantyre north to Loch-Gilphead, the strata all have a general dip to the N.W. I found, first the crumpled coarse gneiss and mica-schist to the south of East Loch Tarbert, gradually falling into more regular stratification towards Barmore, near which a strong band of bluish limestone, quarried at Ashins, and apparently the same as that of Otter, runs across to West Loch Tarbert. After passing Barmore the rock is very siliceous, and continues so all along the base of the lofty ridge of Sliabh Goil on to

Meal Dhu Point, the general character being a sort of granular quartz-rock with little mica. Several large masses of greenstone come out between the beds, and have crumpled them up, and in some cases much altered their mineral texture, but do not seem to derange the succession of the main body of the strata. At Meal Dhu Point, or Strondoir, the rock assumes more mica, and continues to be mostly micaceous with occasional beds of a more quartzy nature on to Inverneil, where seams of green slate begin to show themselves and become more and more numerous until they finally give the character to the whole; and from Ardrishaig to Loch-Gilphead the rock all consists of the thin-bedded green slates, much traversed by greenstone, but dipping constantly to N.W. at low angles. Notwithstanding the prevalence of these greenstones all along the shore here, the passage of the lower grits into the base of the slate-series is clearly indicated; and some of the finely laminated green arenaceous layers noticed near Kildavannan Point occur also in the corresponding part of the section.

Finding, however, no sections along the Crinan Canal to show the upper part of the slates, I betook myself to the ridge of Cruach Lussa (the highest hill in North Knapdale—according to the Admiralty Chart 1530 feet), lying between Loch Fyne and Loch Swen, where I found the passage of the slates into the upper grits well manifested in the south-eastern flank of that mountain.

The base of the hill is here formed of a great thickness of these finely laminated greenish slates, dipping N.W., at a high angle, into the interior of the ridge; and as I ascended I found them pass up into greenish grits, with several thick masses of bedded greenstone. These appear to form all the upper part of the hill; but subordinate slaty seams occur here and there, and one such finely laminated bed passes over the very summit, enclosed between beds of grit and greenstone. The N.W. brow of the hill shows thick strata of coarse gravelly grit, perfectly identical with those in the upper grits of Bute, and showing the same water-worn grains of bluish-hyaline and grey quartz, of the size of peas or beans,—these beds all dipping to N.W. at a very steep angle, accompanied by enormous masses of bedded greenstone, which range from S.W. to N.E. for miles, quite conformably to the strata.

Between Cruach Lussa and the Crinan Canal there is a barren upland tract studded with tarns or little mountain-lochs, several of which have been converted into reservoirs for the service of the canal. This region is highly interesting in a geological point of view, much of the rock being exposed, and showing great parallel ridges of greenstone running along between thick beds of grit, with some intercalated seams of slate and bluish limestone. At least two beds of limestone occur in these upper grits here, but neither of them so thick as that at Otter. They contain a good deal of sand, and seem well adapted for the preservation of fossils; and, although I failed to find in them the slightest trace of organic life, I cannot but think such will yet be found. There are also several finely laminated schistose or slaty beds; but these are seen to be clearly subordinate to the grits, which, with the greenstones, form the predominating features in the geology of this tract. From this to the head of Loch Swen, the dip of the strata becomes nearer and nearer to vertical; and in the neighbourhood of that loch the general position of the strata is almost upright, leaning occasionally to S.E., and occasionally to N.W., but always striking from S.W. to N.E.; and to the west of Loch Swen the character seems to be a mere repetition of those I have been describing. We find the same thick beds of grit and greenstone, accompanied by subordinate seams of slate and indications of limestone, still dipping at high angles; but the inclination is now found to set in to S.E. I therefore think that here we have a synclinal trough whose axis lies in the direction of Loch Swen; and, from the great apparent thickness of the strata, even allowing for many repetitions, I conceive that we have in this district a quantity of beds belonging to the upper grits beyond what is found in Bute, where they terminate abruptly at the border of the Old Red Sandstone.

§ 5. From the descriptions and maps of Macculloch, in his capital work on the geology of the Western Isles, it appears that the easterly dip is maintained all through the islands of Shuna, Luing, and Scarba, on to Jura, subsiding gradually to lower angles, and exhibiting a descending series of grits and greenstones, followed by clay-slate, mica-slate, and quartz-rock, in the very same order as I have described them in Knapdale; and, although I had not time to visit those islands, I have little doubt that in the quartz-rock of Jura we have the western extension of those great siliceous masses that form the lofty ridges of Sliabh Goil and Meal Dhu, between Loch Tarbert and Loch Killisport. The clay-slate forming the eastern border of Jura, and ranging north-east through Scarba, Lunga, and Luing, on to Eisdale, I have as little hesitation in saying, represents the slaty beds of Bute, which, rolling over the anticlinal fold, plunge under the upper grits of Cruach Lussa, and reappear again to the westward in the reversed curve, troughing, as it were, these upper grits; and if the limestone of Islay, Garveloch, and Lismore lies at the base of the Jura quartz-rock, we have that also paralleled by the calcareous masses of Otter, Barmore, and West Loch Tarbert, which lie beneath the quartz-rock of these localities.

With regard to the thickness of these old rocks, taking either side of the anticlinal axis, their enormous dimensions are equally apparent. The mass of lower grits, judging from the Bute section, must be many thousand feet thick; and the group of thin-bedded slates in that island has an apparent thickness of 2000 or 3000 feet; while the upper grits, although far short of the dimensions they seem to attain in Knapdale, form also a considerable body of strata.

§ 6. The greenstones, which I have so often mentioned, form a most remarkable feature in the geology of Knapdale. They attain their greatest development among the upper grits of the synclinal trough, but are not confined to them, and alternate with the strata in huge parallel masses running from S.W. to N.E.; and to such an extent are they developed in many places, as quite to overwhelm the associated strata. From the fact of their being thus interstratified with the slates and grits, Macculloch seems to have regarded them all as aqueous sedimentary masses; for he has inserted no trap or igneous rock in his map where they occur, and has described them as a mere variety of chlorite-schist (see 'Western Isles,' vol. ii. p. 290). They are the typical beds of his "chlorite-series," forming, as he says, nearly three-fourths of it; and it is from them that he has bestowed the name on the group,—quartz-rock being ranked next in quantity.

I was unable, however, to perceive any character whereby they could be distinguished from other greenstones: for they seem to be, for the most part, composed of felspar and hornblende, and have a massive form and crystalline structure like syenite or granite; they may also be occasionally observed resting on the upturned edges of the sedimentary strata; and finally, what seemed to me a conclusive character, they have in many places exerted a powerful metamorphic action on the adjoining strata. On the other hand, it is difficult to conceive how they could be of an eruptive nature, or be injected among the stratified beds posterior to their formation without deranging the disposition of these to a far greater degree than they have done: and, what is even still more singular, there are many huge masses which seem to have exerted no metamorphic effect whatever on the adjoining beds of grit, which display the water-worn grains of quartz in a perfectly similar condition to those of Bute, where no such greenstone is near them.

I have already mentioned that great quantities of greenstone come out between the strata along the west shore of Loch Fyne, between Barmore and Loch Gilp. One of these, near a place marked Milmore on the Admiralty Chart, is about sixty yards broad, and has affected the quartz-strata on both sides, crumpling them up into strongly wrinkled and corrugated masses, whose original greyish-white colour has been changed into various hues of purple, red, and yellow; and there are many segregations of vein-quartz, together with streaks of a red colour strongly impregnated with iron-ore. Their granular texture is also effaced, and they have become compact and close-grained, like hornstone. The lamination and stratification are in some places obliterated, and the rock traversed by numerous fissures. At another spot, near Erins, I observed some wedge-shaped masses of greenstone proceeding from the main body and intruding amongst the quartz, where they thinned out into tendril-like streaks. Near Meal Dhu Point another bed of greenstone, 30 or 40 yards thick, is seen coming out between the quartz-strata, and powerfully affecting them on both sides to a distance of about 20 yards. The stratified rock is crumpled up, loses its ordinary pale greenish-grey hue, and assumes a variegated colour of red, ochrey-yellow, green, and brown, irregularly mingled; while the lamination is in many places quite obliterated, and ravelled veins of quartz ramify through it. Masses of the rock are converted from a quartz-grit into compact jasper-like or hornstone-quartz. The greenstone itself is likewise affected, and traversed by some very odd veins of quartz, which seem to proceed out of the sedimentary rock. Various thinner beds of greenstone are seen near these, interstratified with the quartz-rock and following its undulations. Between Inverneil and Loch-Gilphead I noticed instances where layers of mica-slate, followed along their strike, may be seen gradually to assume a greenstone aspect; these micaceous strata are also often much contorted in the neighbourhood of the greenstone, which is itself occasionally altered and traversed by cream-coloured veins. The action of the greenstone upon the thin-bedded slates may be noticed in the low masses along the shore near Ardrishaig Hotel. Sometimes it has caused a segregation of the mineral ingredients, the quartz forming numerous white streaks parallel to the bedding, together with some larger veins ramifying in a more irregular manner; carbonate of lime has also in some cases segregated along with the quartz; while the chlorite has also in a great measure been purged of its impurities, forming a tough mass which has quite lost its laminated fissile character, and in some cases it appears to pass insensibly into the greenstone. Although neither here nor elsewhere did I notice veins ramifying from the greenstone, yet it has in some cases burst through the strata transverse to the bedding, in good-sized masses. An instance of this may be seen on the shore about halfway between Ardrishaig and Loch-Gilphead, near a place marked Glenburn in the Admiralty Chart, where some greenstone has protruded across the green slaty strata, which become much crumpled as they approach it, and assume an irregular sort of cleavage, or cross-planes of division; they also become more micaceous; and at some points the prolongation of these micaceous slates passes insensibly into the greenstone without any clear line of separation; there is, in short, a gradual conversion of the slate into a massive greenstone; but in other parts the line of meeting is easily seen.

On the shore of Loch Fyne, to the north of Otter Ferry, near a place marked Gortans in the Admiralty Chart, where greenstone has invaded the quartz-strata and caused much alteration and contortion in them, I observed a curious change in the greenstone itself near its contact with the quartz, whereby it assumed a foliated structure, and became highly micaceous—in short, took on the aspect of a greenish mica-schist to the thickness of one or two feet.

I observed likewise instances, both in Bute and Knapdale, where dark fissile clay-slate is changed, near its contact with greenstone, into a substance like basalt. On the line of the Crinan Canal, between Dunartry and Ballenoch, a mass of greenstone is conspicuously seen, the weathered surface of which is full of circular concretions like those often noticed in decomposing trap.

The chlorite-series has been laid down in the map of Macculloch only in Argyleshire; this geologist therefore seems to have regarded it as distinct from any of the other Scottish formations. Under this view we should have the singular fact of an immense succession of sedimentary strata developed here and nowhere else. This I believe to have arisen from his having mistaken a trap-rock for an aqueous sediment.

Another feature of the case even still more singular, if we should, with Macculloch, hold these greenstones to be merely highly metamorphosed aqueous sediments, would be the fact of immense felspathic and hornblendic beds alternating with others remarkable for the absence of both these ingredients, and all deposited from the same sea. It is easily understood how beds of grit should alternate with slate and schist; for the one is the sand, the other the mud of the old sea-bottom, separated by the action of gravity; but it would be difficult to comprehend how the action of sea-water could have sifted so finely grains of felspar from those of quartz, their specific gravity being alike. In the Silurian rocks of Wales and elsewhere, beds supposed to consist of contemporaneous trap or volcanic ash are interstratified with ordinary aqueous sediment; and it is quite intelligible that felspathic matter from an igneous source might be ejected at intervals, so as to be thus interstratified with quartz-sand derived from the erosion of different materials; but in such cases the beds of igneous matter have been distinguished from the ordinary aqueous deposits with which they are associated, by a name marking their proper origin. Whether, therefore, these greenstone-rocks of Knapdale are of contemporaneous formation with the strata beside them, or whether they have been subsequently injected amongst them, they ought in my opinion to be clearly distinguished from the grits and clay-slates, and not classed under the head of a mere variety of these, as they have been by Macculloch. I prefer, then, using the term *bedded greenstone*, as marking this distinction and, at the same time, indicating the fact of their alternation with the stratified layers, as well as conveying a more just idea of their mineralogical features.

I was unable to devote sufficient time for a thorough examination of the district where these bedded greenstones occur, and would recommend the locality to the attention of any geologist who may have the opportunity, as likely to be well worth the labour of an examination; for it is very probable that here there may be greenstones of different ages and various origin. I myself noticed some vertical dykes of trap, of a blacker hue, which were evidently of a later date, running in a N.W. direction, and cutting across both the greenstone and grit, and causing alteration at the line of contact. Two such may be seen in following up the course of the stream that joins the Crinan Canal at Cairnbaan, and down which the torrent descended when the reservoirs burst.

The fact of veins of lead-, copper-, and iron-ores being met with in several parts of this greenstone-traversed district, is a circumstance characteristic of igneous action. In the micaceous strata to the south-west of Inverneil I saw a lode or vein of white quartz, a foot or more thick, which in many places is very rich in galena, frequently accompanied by sulphuret of iron and copper. This vein of quartz is also encrusted in some places with beautiful little crystals of carbonate of iron or sparry iron-ore. Its course is nearly vertical, with a strike about N. 25° W. It had been wrought in former times as a mine, and is now opened anew. Other veins of a similar nature, with some ironstone, are known to occur in the lower grits between Inverneil and Barmore; and I heard that a vein of lead had once been opened, at the rocky point between Loch Gilp and Loch Fyne, and also near Dunartry, in the upper grits.

§ 7. I examined the limestones that came under my notice for fossils, more particularly the thick calcareous grit of Otter, which seemed a likely rock for containing them; but in none did I perceive anything of the kind. In the weathered surface of some of the quartz-grits in Knapdale, both above and below the slates, I noticed numerous circular cavities, and also some curious elongated stripes of coarser sand, which suggested the idea of Annelide-burrows; I could not, however, satisfy myself as to whether such was actually their origin, and must leave it to the decision of those who know more about these matters.

The period at which these old beds of sand and mud had been thrown into undulations and changed into quartz-rock, mica-schist, and slate is evidently very remote; for the Old Red Sandstone conglomerate in the shore beside Rothesay is seen to be made up of the débris of these strata; and it is important to remark that its water-rolled pebbles of siliceous grit, mica-schist, and slate have quite as metamorphic an appearance as the parent rocks from whence they were derived have at the present day. Many of these imbedded fragments show the same contorted, wrinkled, foliated structure, and are traversed by the same ramifying veins of quartz (which had solidified before the water-rolling of the fragments), and, in short, are altogether identical in their mineral complexion with the present features of the rocks I have been describing. Their metamorphism must therefore have been completed before the Old Red conglomerate began to accumulate; and this leads to the conclusion that a great chasm intervenes between the era when these old rocks were formed and that of the Old Red Sandstone, and brings us to assign to them a date anterior to that of the upper Silurian beds. They do not appear to resemble, in mineral features at least, either the "Cambrian sandstone," or the "fundamental gneiss" of Sir Roderick Murchison, described by him as occurring in the North-west Highlands; while they seem to bear a striking resemblance to the quartz-rocks, limestones, and mica-schists of Sutherlandshire, &c., shown by the same geologist to be of Lower Silurian age,—the chief difference being the presence of the bedded greenstone, which, however, is, as I have shown, a local phenomenon, being absent in Bute. So far, therefore, as lithological appearances are entitled to weight, there is reason to believe them to be of similar date to those rocks of the North-west Highlands. However, as mere mineral features alone form a very unsafe criterion in such cases, we must look either for evidence proving the physical synchronism of these beds of Argyleshire with the North-western types of Murchison, or, still better, for some clear fossil-evidence, before we can arrive at a positive determination.

Perhaps the most interesting feature of the district described is the immense development of these bedded greenstones, which may serve as a parallel to the similar phenomenon in Wales; and to this I would beg to draw the further attention of those interested in the study of trap-rocks.

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2. *On the* POSITION *of the* BEDS *of the* OLD RED SANDSTONE *developed in the* COUNTIES *of* FORFAR *and* KINCARDINE, SCOTLAND. By the Rev. HUGH MITCHELL.

[Communicated by the Secretary.]

§ 1. THE time has now come for us safely to pronounce, from palæontological evidence, upon the place of those fossiliferous flagstones, with their associated sandstones and conglomerates, which are spread over a large territory in the counties of Forfar and Kincardine, and which are referred to in a paper* read by Prof. Harkness before the Geological Society on the 18th January of this present year †.

The superficial area of country referred to in this paper is almost the same as that in the paper of Prof. Harkness, namely a district, comprehending all the lowland parts of the two counties, bounded on the north by the Grampian Mountains, impinging on the west on the County of Perth, and bounded on the south and east by the German Ocean. The objects of the papers are, however, very different. Prof. Harkness illustrated the stratigraphical arrangement of the rocks by numerous sections along the northern boundary-line, where they lean against the crystalline schists of the Grampians; our attention is now directed more to the beds as spread out and exhibited in the beautiful tract of country to the south-east of the mountains, and which have of late years begun to yield not a few characteristic and important fossils. It is now wished to state the palæontological data, collected by the writer in the course of several years, which lead to certain conclusions, in his opinion, sufficiently determining the position and the importance of these rocks in the geological scheme ‡.

* Entitled "On the Association of the Lower Members of the Old Red Sandstone and the Metamorphic Rocks on the Southern Margin of the Grampians," Quart. Journ. Geol. Soc., vol. xvi. p. 312.

† See also a paper by the author "On the Flagstones of Forfarshire," 'Geologist,' 1859, vol. ii. p. 147; his "Notice of New Fossils from the Lower Old Red Sandstone of Scotland," 'Geologist,' 1860, vol. iii. p. 273; and Mr. W. Powrie's paper "On the Old Red Sandstone and its Fossil Fish in Forfarshire," *ibid.* p. 336.

‡ The reader is referred to the 11th chapter of 'Siluria,' 2nd edit., 1859, for the latest and most complete review of the history of the Old Red Sandstone, and for the corrections made by Sir R. I. Murchison in the correlation of the several members of this group. The Table at pp. 432 & 433 of 'Siluria' gives a general view of the classification adopted by Sir Roderick,—the Upper, Middle, and Lower divisions of the Old Red Sandstone of Scotland being respectively synchronized with different zones of the Old Red and Devonian rocks of England and Europe.—EDIT.

§ 2. *Fossils occurring in the Lower Old Red of Forfar and Kincardineshire.*—With one exception (*Stylonurus*), which is in the possession of Mr. Powrie, of Reswallie, the writer can produce from his own cabinet the fossils enumerated in the annexed Table; but there are still many undescribed *Ichthyodorulites* and separated scales of fishes, which it is believed indicate other new genera and species. There are also unnamed species (if not genera) of the family of the *Eurypteridæ* among the *Crustacea*. It must not be forgotten that in these rocks there is also a unique but fragmentary flora, of which the only form at all resembling any recorded species is an organism almost identical with that figured in plate 35. fig. 30 of 'Siluria,' and which Dr. Hooker considers to be the spores of some cryptogamic land-plant*. There are also forms in the author's possession about which only a conjecture can be hazarded. From one locality slabs have been procured containing imprinted on their surfaces all the phenomena of a sea-shore of the period—Annelide-tubes, Annelide-tracks, a great variety of Crustacean tracks, rain-prints, and desiccation-cracks.

Carboniferous.	Upper Silurian.	Fossils occurring in the Lower Old Red Sandstone of Forfar and Kincardineshire.		In the Old Red Sandstone of Herefordshire.	In the Old Red Sandstone north of the Grampians.
	*	*Cephalaspis*	*		
		Cephalaspis Lyellii, *Agass.*	Abundant	*	
		Ptychacanthus dubius, *Agass.*	*	*	
*		*Acanthodes*	*	...	*
		Acanthodes Mitchelli, *Egert.*	Abundant.		
		Brachyacanthus scutiger, *Egert.*	*		
		Diplacanthus	*	...	*
		Diplacanthus, 2 spp. nov.	*		
	*	*Plectrodus*	*		
	*	*Onchus*	*	*	
		Onchus, 2 spp. nov.	*		
*		*Ctenacanthus*	*	*	
		Ctenacanthus, 2 spp. nov.	*		
		Parexus incurvus, *Agass.*	*		
		Climatius reticulatus, *Agass.*	*		
		Stylonurus Powriensis, *Page*	*		
		Kampecaris Forfariensis, *Page*	*		
	*	*Eurypterus*	*	*	
	*	*Pterygotus*	*	*	
		Pterygotus Anglicus, *Agass.*	Abundant.		
	*	*Parka*	...	*	
		Parka decipiens, *Flem.*	Abundant.		
		Vegetable remains	Abundant.		
	*	Spores of a land-plant (*Pachytheca*, Hooker)	*		

* *Pachytheca*, Hooker, MS. See also Quart. Journ. Geol. Soc. vol. ix. pp. 10 & 12; and 'Siluria,' 2nd edit. p. 267, *note*.—Edit.

On some of the fossils in the above list, a few brief remarks may be allowed. *Cephalaspis Lyellii*, figured by Agassiz, is from Glammis, Forfar; it is by no means rare. *Ptychacanthus dubius* appears, from specimens in the writer's possession and in the cabinet of Mr. Walter M'Nicol at Tealing, to be the posterior portion (serrated along the inner margin) of the head-plate of a species of *Cephalaspis*.

The Acanthodian fishes are new to science, and are about to be described by Sir Philip Egerton in a 'Decade' of the Geological Survey. *Plectrodus* has only recently been found here; and any day the stroke of the hammer may expose to our examination the complete form of this curious creature.

§ 3. The fossils connecting the Forfar and Kincardineshire beds with the Upper beds of the Silurian System as developed in the typical region of the latter, belong to the genera *Cephalaspis*, *Plectrodus*, and *Onchus* among the Fishes, and the genera *Pterygotus* and *Eurypterus* among the *Crustacea*. There is also the curious organism known as *Parka*. It may be questioned if our beds have one *species* in common with the Ludlow rocks, although several *genera* seem to range through both.

§ 4. The fossils connecting the Forfar and Kincardineshire beds with the higher beds of the Old Red Sandstone belong to the genera *Acanthodes*, *Diplacanthus*, and, in a sense, *Ctenacanthus*. *Acanthodes* rises into the Middle Old Red Sandstone, and is also found in the Carboniferous rocks. *Diplacanthus*, if it be that genus which occurs in the Lower, advances no further than the Middle Old Red. *Ctenacanthus*, though not recorded from either the Middle or Upper Old Red Sandstone, finds its way into the carboniferous rocks.

§ 5. The fossils occurring both in the Old Red Sandstone of Herefordshire and in that of Forfar and Kincardineshire are *Cephalaspis Lyellii* and *Ptychacanthus dubius*, with the genera *Onchus*, *Ctenacanthus*, *Pterygotus*, *Eurypterus*, and *Parka*.

§ 6. With regard to the fossils peculiar to the Forfar and Kincardineshire beds or to their equivalents in England, and determining them to belong to a distinct and well-marked zone of the Old Red Sandstone, it may be said that the entire Fauna and Flora are peculiar. There may be one or two doubtful cases, so far as specific identity is concerned; but the facies is undoubtedly characteristic of the horizon of these beds. The genus *Parka* is highly characteristic.

§ 7. *Distribution of the Fossil Remains over the Counties of Forfar and Kincardine.*—Over this extensive area there is almost complete identity in the fossil organisms. Of this some illustrations may be given. *Cephalaspis Lyellii* has been found over the entire district from Balruddery on the S.S.W., and on the confines of Perthshire, to Canterland, close upon the German Ocean, in Kincardineshire—as at these particular localities:—Balruddery, Tealing, Glammis, Carmylie, Leysmill, Carsegownie, Brechin, and Canterland. The Acanthodian Fishes are now known to occur in five localities:—Balruddery, Tealing, Forfar, Farnell, and Canterland. These fishes were first detected by the author in beds at Farnell in July 1857; but they are now turning up over the whole district. *Parexus incurvus* is founded, by Agassiz, on a very striking spine from Balruddery, but has also been detected by me at Canterland, the other extremity of the district. *Parka decipiens*, occasionally with an attached ligament or stem, or even with what resembles a calyx or sheath, is universal, and abundant in every section and in every quarry. *Pterygotus* is almost as widely dispersed, though generally in a fragmentary condition ; and for it the same localities may be stated as for *Cephalaspis*, with the exception of Brechin, but substituting in place thereof Farnell, where plates of the larger Crustaceans and complete forms of the smaller have been found by the author and Mr. Powrie of Reswallie. *Kampecaris* was described by Page from Balruddery, and has been found (perhaps several species) by me at Canterland, the extreme of the area. Some of the vegetable forms are generally diffused, like *Parka decipiens*, occurring in every opening of the fossiliferous beds. Indeed the only form, with the exception of the *Crustacea* (which are yet undescribed), confined to one locality is *Climatius reticulatus*, recorded by Agassiz from Balruddery ; but the genus is founded on a spine, and in the multitude of our spines it might be easily passed over.

§ 8. *Distribution of the Fossils through the vertical depth of the Strata.*—Though spread over a wide area, the arrangement of our rocks is very simple. In the section at Canterland (which is typical of the district) we have, first and lowest a gritty sandstone* (120 feet seen), very ferruginous, and containing occasional thin layers of a purplish flag ; secondly, grey flagstone with intercalated sandstones (40 feet)†; and thirdly and above all, an overlying conglomerate‡. A similar life seems to have prevailed throughout the entire formation, as embracing an era in geological time. We have met with a solitary but well-preserved *Parka decipiens*§ far beneath the fossiliferous grey beds in the gritty sandstone which forms the bottom-rock in the Canterland section. The *Cephalaspis* is found occasionally in the sandstones used for building-purposes, as at Brechin (immediately below the grey flagstones), in which, owing to the nature of the matrix, not another organism is known. But whilst this is all the direct palæontological evidence, there is other evidence of a physical character. Among the purple flags, which lie very low in the formation, there have been gathered slabs containing on their surfaces impressions, numerous and well marked, of what we may call the phenomena of a sea-shore of this palæozoic epoch. On that sea-shore the tides must have ebbed and flowed, the rain have fallen, now in heavy shower, anon in drizzling mist, the sun must at times have shone with sultry beam, and many creatures have travelled across the *palimpsest* surface. Besides the Annelide-markings, we have

* Judging from the dip and the neighbouring rocks, this sandstone probably rests on a dark-red sandstone.

† In the quarries at Carmylie these are 120 feet thick.

‡ A few feet thick here, but several hundred feet thick as it rises up the neighbouring hills. At the Hill of Turin, conglomerate (2 feet thick) is intercalated amongst the grey flagstones.

§ Sir R. I. Murchison and Mr. Powrie found the *Parka decipiens* common in the lower conglomerates on the mountain or western flank of the basin.—Edit.

counted at least eight forms of Crustacean tracks, indicating an assemblage at the time, on that ancient sea-beach, of creatures similar in size and organization to their congeners preserved in higher beds of the formation, namely the grey flagstones. Although the number of limbs attached to these ancient Crustaceans may still be matter of doubt, yet we have in their stone impressions such a character as would, on the one hand, be made by a gigantic *Pterygotus*, and on the other, such as would be made by a creature as small as the Sandhopper of our present shores, besides various intermediate forms corresponding with the remains found in the flagstones. From such evidence (and we think it must be allowed) do we infer the existence of a similar life throughout the formation, even when all trace of the organism has itself perished.

OLD RED SANDSTONE.

Upper	Holoptychius-beds of Moray, Perth, and Fife.	
Middle	Fish-beds of Cromarty and Caithness.	
Lower (10,000 feet thick in Forfar) .	Conglomerate. [Canterland Den.]	
	Grey flagstone with intercalated sandstone. ("Cephalaspis-beds.") [Canterland Den (40 feet thick here, 120 feet at Carmylie), near Farnell, &c.]	*Cephalaspis Lyellii.* Ichthyodorulites. Acanthodian fishes. *Pterygotus Anglicus.* *Kampecaris Forfariensis.* Vegetable remains, &c.
	Gritty ferruginous sandstone, with occasional thin layers of purplish flagstone. [Canterland Den (120 feet here seen), Ferryden, &c.]	*Cephalaspis* (in sandstone at Brechin). Ripple-marks, Rain-prints, Worm-markings, Crustacean tracks (large and small, *on the flags*). *Parka decipiens* (in the lowest grit*).

§ 9. Some of the general conclusions to which the palæontological data seem to lead us may be stated as follow:—

First, it must be granted that in these beds developed in the counties of Forfar and Kincardine in Scotland, and their equivalents in England, we have the lowest members of the Old Red Sandstone. We do not venture to determine what those metamorphic rocks are upon which, on the western side of our district, the Old Red Sandstone rests; we leave that point for future decision, either by the discovery of fossils in some part of the Grampian chain or by the clear unfolding of their stratigraphical relations. We hold, however, that the position of the beds the palæontology of which we have here endeavoured to describe may now be held as fully ascertained. They are the foun-

* And also in layers which alternate with coarse lower conglomerates on the S.E. flank of the Grampians.—Edit.

dation of that great series of rocks which for our northern land was first described by Sedgwick and Murchison, and since rendered classical in the literature of the age by the writings of Hugh Miller. Though it is matter of doubt if any one of the species found in these beds occurs in the system beneath, yet there are genera in common. There are thus links binding them without a gap to the past stage of life and its conditions. Still, in the abundance and variety of the fish-remains, and in the introduction of new forms, as well as in the tokens of a terrestrial surface, we feel that we have entered into a new epoch and a new domain of created existence. There has been in some minds a hesitation to accept these rocks as the basis of the system; but we think the evidence adduced is conclusive on this point.

Secondly, the review of the peculiar fauna and flora of these lower beds of the Old Red Sandstone affirms the necessity of subdividing the system into formations, and of assigning to the Forfarshire flagstones (with their associated sandstones, cherty limestones, and conglomerates) the place of the Lower formation in this extensive group of strata. The thickness of our Forfarshire beds is enormous, 10,000 feet at least. In these rocks we have a facies of animal and of vegetable life characteristic and distinct from that of the Upper and Middle formations; a subdivision is therefore demanded for the purposes of classification. Between the Lower and Middle and Upper beds of the system, there is a marked hiatus: for *Cephalaspis* has never yet been found but in the Lower formation; and when we leave that, not only is Crustacean life at once and immensely diminished in its numbers, but its types are completely changed.

From the recorded observations of Mr. Geikie, there seem to be other areas, of great extent, in Scotland over which this Lower Old Red Sandstone is known to spread; and its area in England is very considerable. We have thus all the elements of value in constituting a formation in geological classification, namely superficial development over extensive areas, great (we may say enormous) depth of strata, considerable variety of mineral conditions (in conglomerates, flagstones, sandstones, and cherty limestones), and a peculiar palæontology.

Thirdly, we claim the right of the Old Red Sandstone as a whole to be admitted and fully recognized as one of the great systems in geology, both on the ground of what has been now advanced and from all previously recorded knowledge of the Middle and Upper formations. The series of rocks called the "Old Red Sandstone" is as large as almost any of the well-marked and acknowledged divisions into which, at the call of Science, the strata of the earth have been made to fall. The system in Scotland alone covers an immense extent of ground. There are large patches of it flanking the Silurian strata in the south of Scotland—in Berwickshire, Roxburghshire, Lanarkshire, and Ayrshire. There is the great development of it in the central district of Scotland, comprehending all the lowland portions of Kincardineshire, Forfarshire, Perthshire, Stirling, and Dumbartonshire, with many an offshoot into neighbouring counties. It stretches on the east far out into the German Ocean, as we know by the Bell Rock. We have tracts of the Old Red, more or less continuous, along the shores of Aberdeenshire, Banffshire, Moray, Nairn, Inverness, Cromarty, and Caithness—covering this entire county and then grasping all the Orkneys in its wide embrace, and stretching out even to the remote Shetlands.

It is quite possible that some of the Old Red beds north of the Grampians were laid down contemporaneously with the beds to the south, and therefore that we have in the respective faunas or floras of both a life existing in the same era, but placed in different regions and in somewhat different conditions. But, even after this reduction of the vertical depth of the entire system, there would yet remain two great divisions, an Upper and a Lower, which cannot be put into parallel ages. If our interpretation of the obscure vegetable remains and the sea-shore-markings be correct, we have, from the very commencement of the era of the Old Red Sandstone, indications of the existence of land-surfaces; while in the waters there was such an abundance of piscine life as to mark the period, throughout, as one of the most memorable in the past history of our globe.

January 9, 1861.

William Charles Lucy, Esq., Gloucester; Robert Dukinfield Darbishire, Esq., B.A., 1 Heald Grove, Rusholme, Manchester; George Charles Wallich, M.D., 17 Campden Hill Road, Kensington, were elected Fellows.

The following communications were read:—

1. *On the Distribution of the* Corals *in the* Lias. By the Rev. P. B. Brodie, M.A., F.G.S.

[Abstract.]

From observations made by himself and others, the author was enabled to give the following notes:—In the Upper Lias some Corals of the genera *Thecocyathus* and *Trochocyathus* occur. The Middle Lias of Byfield, Northamptonshire, and Ilminster, Somersetshire, has yielded a few Corals. The uppermost band of the Lower Lias, viz. the zone with *Ammonites raricostatus* and *Hippopodium ponderosum*, contains a *Thecocyathus*, numerous at Cheltenham and Honeybourne in Gloucestershire; and a *Montlivaltia* in considerable abundance at Down Atherley in Gloucestershire, at Fenny Compton in Warwickshire, and more rare at Aston Magna in Worcestershire, and at Kilsby Tunnel in Northamptonshire. The middle members of the Lower Lias appear to be destitute of Corals. In the zone with *Ammonites Bucklandi*, called also the Lima-beds, a *Cladophyllia* is found at Down Hatherley and Bushley in Gloucestershire; and in the same beds at Inkberrow, Evesham, Binton, Wilmcote, and Harbury, in

Warwickshire, and at Shepton-Mallet in Somersetshire, an *Isastræa* occurs. Dr. Wright states that *Isastræa Murchisoni* has been met with in the next lowest bed of the Lower Lias, namely the White Lias, with *Ammonites Planorbis* at Street in Somerset; and another Coral has been found in the same zone at Whitnash and Itchington in Warwickshire. Lastly, in the "Guinea-bed" or "Guineas" at Binton in Warwickshire another Coral has been met with.

The *Montlivaltiæ* of the Hippopodium-bed and the *Isastrææ* of the Lima-beds appear to have grown over much larger areas in the Liassic sea than the other Corals here referred to.

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2. *On the* Sections *of the* Malvern *and* Ledbury Tunnels (Worcester *and* Hereford Railway), *and the intervening Line of Railroad.* By the Rev. W. S. Symonds, F.G.S., and Alan Lambert, Esq. *With a Note on the* Fossils; by J. W. Salter, Esq., F.G.S., of the Geological Survey of Great Britain.

In a paper published in the Edinburgh New Philosophical Journal for April 1857 (p. 257), I described briefly the "Correlation of the Triassic Rocks in the Vale of Worcester and at the Malvern Tunnel." These rocks have the following order on the flanks of the Malverns:—

1. Upper Keuper Marls.
2. Upper Keuper Sandstone.
3. Lower Red or Keuper Marls.
4. Lower Keuper Sandstones (Waterstones).
5. Upper Red Sandstone (Bromesberrow beds).
6. Lower Red Sandstone (Stourport beds).

No. 6. The lowest of these deposits is a dark-red sandstone with black patches, and closely resembles the "Lower Red Sandstone" of the geological surveyors in mineralogical character. It is to be seen at the back of the stables of the Belle Vue Hotel at Great Malvern, dipping from the hill, to the south-east, at an angle of 60°.

A large erratic block, angular and with no sign of subaqueous action, was found imbedded in this dark-red sandstone. This erratic block is different to any rock now exposed in the Malvern district, and appears to me to belong to the Cambrian grits of North Wales, or possibly to that of the Longmynd. It may be seen in the Museum of the Malvern Field-Club at the Messrs. Burrow's, Great Malvern.

No. 5. This Upper Red Sandstone (Bromesberrow beds) may be studied with advantage at the village of Bromesberrow, where it overlies the Haffield or Permian breccia of Prof. Ramsay and the Geological Survey Map, and is covered by the Waterstones of the Newent district.

No. 4. Lower Keuper Sandstones (Waterstones).

A patch of these sandstones flanks the Chase End Hill of the Southern Malverns, and ranges from a wood at the back of the Hawthorns, in the parish of Berrow, towards Bromesberrow Place, the seat of Mr. Osman Ricardo, M.P. for Worcester. Again they may be seen covering the Bromesberrow sandstones near the Glynch Brook, and ranging south towards Red Marley D'Abitot, where they are faulted against the Lower Keuper Marls, which should surmount them.

No. 3. Lower Red Marls.

These soft marly beds are well exposed in the lateral valleys in the Malvern district. These are valleys of denudation, and in most instances occur where anticlinals of Keuper Sandstone have been broken and the apices or ridges of the anticlinals removed.

No. 2. Upper Keuper Sandstones.

These fossiliferous sandstones have been generally denuded along the Malvern Vale. Wherever I have studied them, they are mere relics of a series of low anticlinals.

No. 1. Upper Grey and Red Marls.

These rocks are the uppermost Triassic deposits, and at the Berrow Hill, within two miles of the Chase end of the Malvern ridge, pass upwards conformably into the Lower Lias, with the characteristic fossils.

I now refer to the section of the tunnel at Malvern Wells, on the Worcester and Hereford Railway, prepared by Mr. Alan Lambert and myself, and for the admeasurements of which I am indebted to Mr. Lambert, one of the engineers upon the line, who has assisted me throughout this somewhat arduous undertaking with the utmost courtesy and good will. Mr. Lambert has prepared a section (reduced in fig. 1) of the line of railway, from the entrance of the Malvern tunnel to the exit of the Ledbury tunnel on the Hereford line, for the Geological Society of London, at the request of Mr. Liddell, the chief engineer of the railroad.

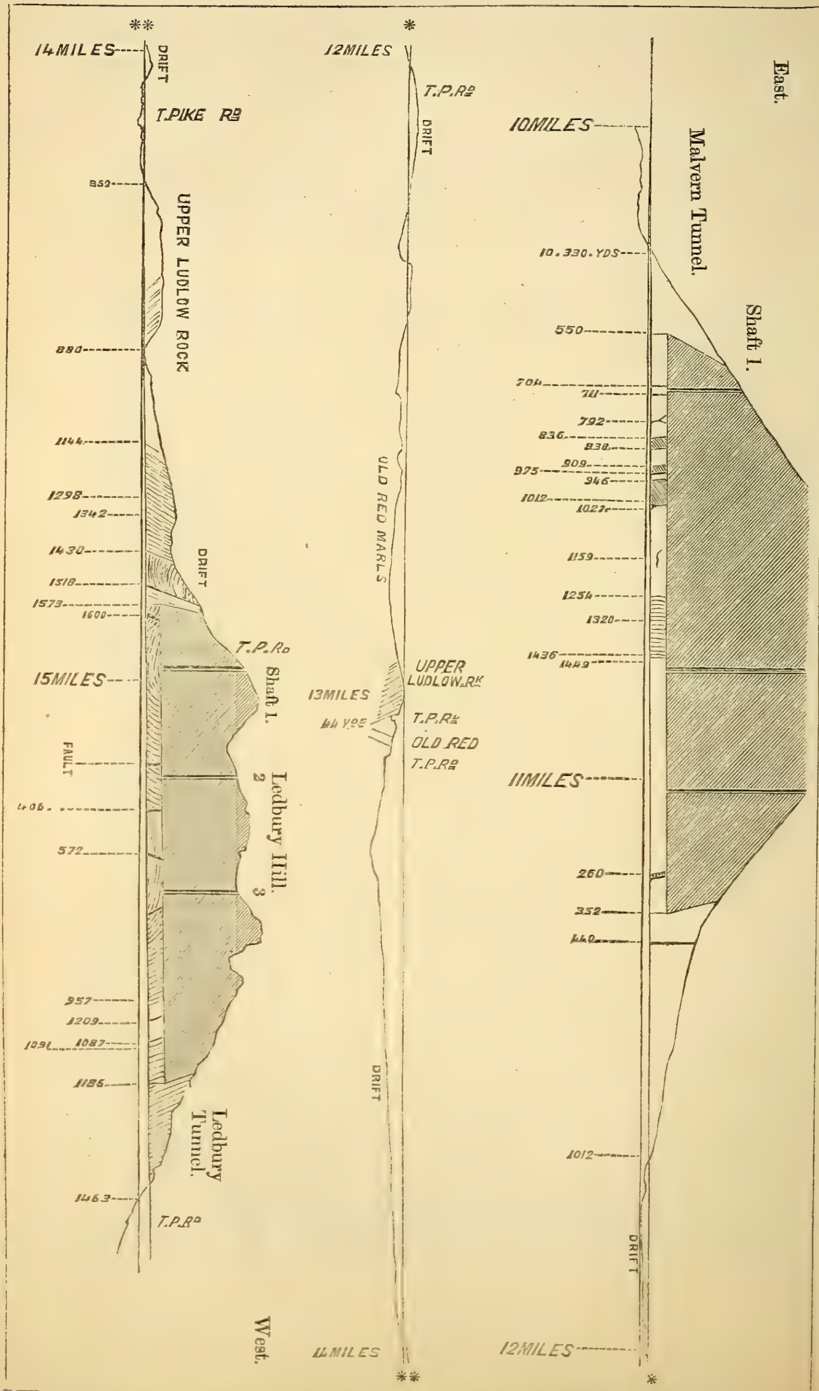
The entrance of the tunnel (see Section, fig. 1, and the Explanation) commences with the Upper Keuper Marls (10 m. 330 yds.), overlain by a considerable thickness of subangular drift, which has furnished the bones and teeth of *Bos primigenius*, of *Elephas primigenius*, and of *Rhinoceros tichorhinus*. The site where these mammalian relics were discovered is near the Station at Malvern Wells. Some of these fossils are in my possession, and some are at Worcester Museum. The Upper Keuper Marls at the tunnel's mouth have been much denuded. In the tunnel they pass into the Keuper Sandstones and Marls with the *Estheria* and fragments of teeth and spines of *Lophodus* (formerly *Acrodus*).

These deposits are much broken and contorted, and pass into a series of red marls, which, I do not doubt, are the representatives of the Lower Keuper Marls (10 m. 550 yds. to 704 yds.).

The Lower Keuper Marls dip away from a syenitic and brecciated rock, against which they rest conformably at an angle of 50°.

It is worthy of observation that the Lower Keuper Sandstones (Waterstones) and the Red Sandstones of Bromesberrow are *entirely wanting* in the tunnel. I was puzzled, at first, whether or not to rank the brecciated syenite as an equivalent of the Haffield Permian breccia, as there is evidence of stratification. The stratifi-

Fig. 1.—*Section on the Worcester and Hereford Railroad, beginning at 10 miles 330 yards from Worcester, and ending at 15 miles 1463 yards; including the Malvern and Ledbury Tunnels.*



Scale 500 yards to the inch, horizontal : 160 yards to the inch, vertical.

Explanation of the Geological Section on the Worcester and Hereford Railroad, from 10 *miles* 330 *yards from Worcester to* 15 *miles* 1463 *yards*.—See Fig. 1.

	Miles.	yds.	
At	10	330.	Keuper Marls, red with grey bands.
	,,	550.	Tunnel commences.
From	,,	550.	to 10 m. 704 yds. Keuper marls and sandstone, twisted and broken; sometimes nearly horizontal, and sometimes with a dip of 50°.
At	,,	704.	Syenitic breccia and thin band of black schist: dipping at an angle of 58° towards the hill.
	,,	711.	Syenite.
	,,	792.	Thin band of chlorite, with black schist in contact.
	,,	836.	Chlorite, with syenite caught up.
	,,	858.	Syenite.
	,,	909.	Greenstone.
	,,	925.	Syenite.
	,,	946.	Greenstone.
	,,	1012.	Black hornblendic rock, with highly crystallized felspar, with overlying greenstone.
	,,	1037.	Syenite.
	,,	1159.	Two thin bands of Llandovery limestone, about 6 in. thick, with 2 ft. of marl.
	,,	1160.	Syenite.
	,,	1254.	Llandovery shales and limestone in thin bands, pressed against syenite; syenite overhanging.
	,,	1320.	Woolhope shales.
	,,	1436.	Woolhope limestone.
	,,	1449.	Wenlock shales and thin bands of sandstone.
At about	11	260.	Wenlock limestone (thickness uncertain).
Up to	,,	440.	Lower Ludlow shales.
At	,,	440.	Old Red marls, with thin bands of grey and red sandstones.
From	,,	1012	to about 13 m. Local drift and red marls.
At about	13	0.	Ludlow rock.
	,,	44.	Old Red, lying unconformably against Ludlow rock.
From	,,	44	to 14 m. 352 yds. Local drift and red marls.
At	14	352.	Upper Ludlow rock.
	,,	880.	Old Red marls.
	,,	1144.	Upper Ludlow rock.
	,,	1298.	Aymestry rock.
	,,	1342.	Lower Ludlow rock.
	,,	1430.	Local drift, 40 ft. thick, overlying drift derived from Old Red Marl: Lower Ludlow rock beneath.
	,,	1518.	Upper Ludlow rock.
	,,	1600.	Aymestry rock.
From	,,	1600	to 15 m. 406 yds. Ludlow and Wenlock shales.
At	15	406.	Wenlock limestone, horizontal.
	,,	572.	Lower Ludlow rock, angle 12°, north, passing at about 886 yards to 75°, south.
	,,	957.	Aymestry rock, angle 75°, south.
	,,	1029.	Upper Ludlow shales, angle 75°.
	,,	1087.	Downton sandstone, angle 75°.
	,,	1091.	Passage-beds into the Old Red Sandstone, angle 75°; thin bands of grey and red sandstones.
	,,	1186.	Tunnel's mouth.
	,,	1463.	Section ends.

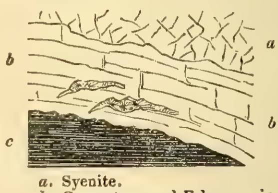
cation, however, is but partial, and I am inclined to look upon the brecciated rock as a portion of an ancient beach or talus derived from the syenitic ridge. We observed a thin band of black hornblendic schist in contact with the syenitic breccia; and both these rocks have undergone so much derangement as to dip at an angle of 58° into the hill.

On reference to the section, we find a mass of syenite (at 10 m. 711 yds.) constituting the *external walls* of a nucleus which forms the centre of the Malvern range, and which nucleus is of great interest to the geologist and mineralogist. The thickness of the syenitic crust on the *eastern* side of the Malverns is 125 yards. It is much broken, and will require bricking and roofing in the tunnel.

Traversing the syenite, we found a bed of chloritic rock (at 10 m. 792 yds.) with a vein of shining, coal-black, graphite-looking schist in contact, see fig. 2. Another wall of syenite is succeeded by a

Fig. 2.—*Section in the Malvern Tunnel, showing veins of Quartz and Graphite in the band of Chlorite in the Syenite, at* 10 *m.* 792 *yds.* By Capt. Selwyn.

Fig. 3.—*Section in the Malvern Tunnel, showing veins of Felspar in the Greenstone overlying black hornblendic or dioritic rock, at* 10 *m.* 1012 *yards.* By Capt. Selwyn.



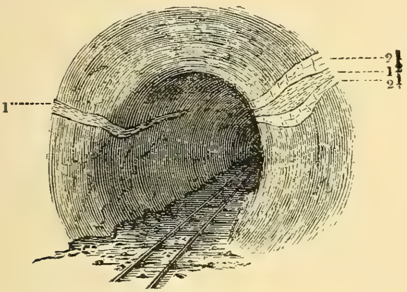
a. Syenite.
b. Greenstone and Felspar-veins.
c. Hornblendic rock.

vein of chlorite with highly crystallized bands of syenite. Here the syenite again sets in in a solid mass, and we pass onwards to a mass of greenstone (10 m. 909 yds.) of the hardest material, and 160 yards thick. The greenstone appeared to me to have been injected when fluid into a fissure in the syenite, the syenite being fissured in a line with the range of the Malverns. It is worthy of remark that the syenitic rock is much crystallized where it is in contact with greenstone.

Leaving this mass of greenstone, we find a remarkable black and greenish rock (hornblendic), containing many veins of red felspar. It has greenstone on both sides. This great amount of change in mineral structure in so narrow a compass could hardly have been imagined, had not the interior of the Malverns been laid open to our investigation. See fig. 3.

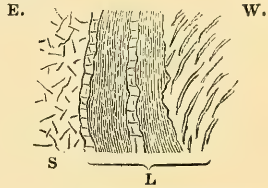
We pass next into a strong rock of syenite (10 m. 1037 yds.), 147 yards in thickness, and which we may consider as the external *western* crust of the Malvern plutonic range. We were astonished to find, almost in the centre of this solid syenite (for the syenite on the western side is not nearly so much shattered as that on the eastern flank), two thin bands of Llandovery limestone, with strata of marly shales 2 feet thick lying in a *fissure* of the syenite. Fig. 4.

Fig. 4.—*Section in the Malvern Tunnel, showing a seam of Llandovery rock in the Syenite, at* 10 *m.* 1254 *yds.* By Capt. Selwyn.



1 Shale. 2 Limestone.

Fig. 5.—*Section in the Malvern Tunnel, showing the Junction of the Silurian rock and the Syenite, at* 10 *m.* 1254 *yds.* By Capt. Selwyn.



L. Llandovery shales and limestones.
S. Syenite.

This Llandovery limestone (formerly "Caradoc" of Murchison) contains some characteristic fossils; and the shales have furnished a *Pentamerus*. Neither the limestone nor shales are in the slightest degree metamorphosed. The fissure runs from north to south, and becomes smaller towards the south. These sedimentary deposits were evidently deposited in a fissure in the syenite during that far distant epoch when the waves of the Upper Llandovery seas washed above the syenitic ridge of the Malverns, and when this interesting and instructive range of hills was a low submarine ridge, of plutonic origin, and of which the *syenitic crust* was, even in the Upper Llandovery epoch, as much cooled, consolidated, and mineralized as at present.

I mentioned that the Lower Keuper sandstones, the Bromesberrow sandstones, and the Haffield Permian breccia (?), which are all to be seen at the southern extremity of the Malverns, are wanting in the tunnel on the eastern or Worcester side of the Malverns. It is somewhat remarkable, also, to find that the Cambrian (Holly-Bush) sandstones and Lingula-flags (black shales) of the Chase End, Ragged Stone, and Midsummer Hills (South Malverns) should be altogether absent on the western flank of the hills of the Wells. The syenite passed, we find limestones and shales, of the Upper Llandovery epoch, full of fossils, resting perpendicularly against the external wall of syenite. Fig. 5. We have evidences of great pressure and crushing, but not a symptom of *metamorphism*; and I exhibit a portion of shale, containing the *Pentamerus lævis*, which was obtained by Captain Peyton close to the line of junction. The Rev. Reginald Hill, of Bromesberrow, Hon. Secretary to the Malvern Field-Club, was the first to disinter these fossils of the Llandovery rock from their long resting-place; and to him, to Captain Peyton, of the Bartons, Ledbury, and to Captain Selwyn, I would express my kind acknowledgments for their assistance in unravelling the secrets of the Malvern tunnel.

It is difficult to ascertain the thickness of the Upper Llandovery rocks here (10 m. 1254 yds.), or to determine any line between them and the overlying shales; they are conformable, and pass one into the other without any perceptible change, excepting in their colour, as, from a purplish grey, they change into a blue mass of shales with thin bands of limestone and grey and brown sandstones. I have thought it necessary, however, to draw a distinction between the Llandovery rocks which rest against the syenite and contain purplish shales with *Pentameri*, and the shales that underlie the Woolhope limestone, because at a certain point I found the Pentamerus-shales were overlain by a sandstone also containing Llandovery fossils, but which is the rock formerly known as the "Caradoc sandstone of the Malverns," underlying the Eastnor Obelisk and cropping out along Howler's Heath. At this point of the section, therefore, I have drawn a somewhat arbitrary line, and have designated the shales above this sandstone as Woolhope shales (10 m. 1320 yds.). Dr. Grindrod, of Malvern, has a fine collection of fossils from these Woolhope shales, and also some splendid slabs with *Pentameri* from the Llandovery shales.

The Woolhope limestone (10 m. 1436 yds.) is quarried in the tunnel within a short distance of the shaft No. 2; and we then pass on into the well-known Wenlock shales (10 m. 1449 yds.). The distance from the Woolhope limestone to the point where the Llandovery rocks rest against the syenitic ridge is nearly 200 yards; and it is therefore evident that the sedimentary rocks were deposited at this particular point of the Malverns in a little bay, or coomb, in the syenite. This peculiarity was pointed out to me several years since by my late friend Mr. Hugh Strickland.

From shaft No. 2 to the mouth of the tunnel on the Ledbury or western side of the Malverns, the railroad passes through Wenlock shales, and strikes the Wenlock limestone (11 m. 260 yds.) at the distance of about 260 yards from shaft No. 2. Here we have evidences of a considerable fault: near the tunnel-mouth (11 m. 352 yds.) the Wenlock limestone is thrown down horizontally, the greater part of the Lower Ludlow rock is wanting, the whole of the Aymestry limestone and the Upper Ludlow shales are deficient, and some sandstones and marls of the Old Red series (and these certainly not the lowest Old Red deposits) are faulted against a regular "scrunch" (to use a miners' phrase) of the Lower Ludlow clays. The Malvern greenstone was not so difficult to work (as I have been assured by Mr. Ballard, the contractor) as this "jammed and scrunched clay" (11 m. 440 yds.).

From hence the railroad passes, for a considerable distance, over red clays and marls covered with local drift; and there is nothing worthy of attention until we reach the road that leads from Colwall to Ledbury. In the lane ascending towards The Bartons, the seat of Mrs. Peyton, we see the Upper Ludlow shales dipping towards the vale in which the railroad runs. At the base of the hill is a bridge constructed for railroad-purposes, and at this spot the workmen quarried the Auchenaspis-grits of the Lower Old Red Sandstone, placed, at an angle of seventy degrees, on the clays of the Upper Ludlow, and reversed*. On reference to the Ledbury section, it will be seen that there is a great thickness of rock between the Auchenaspis-grits and the Upper Ludlow shales.

For some distance the railroad cuts through local drift, until, a short distance after crossing the highroad from Worcester to Ledbury, we pass through a section of Upper Ludlow rock, with abundance of characteristic fossils (13 m. 352 yds.).

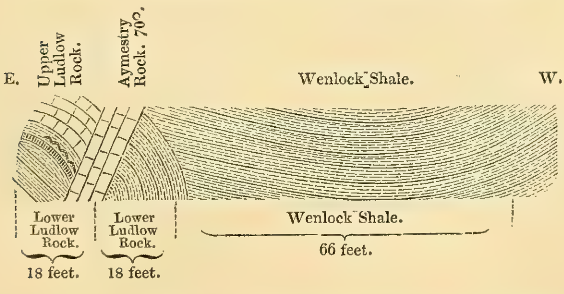
We have next a small basin in which, besides the local Silurian drift, there is a mass of red and grey clays, evidently derived from the denudation of the Old Red Sandstone (13 m. 880 yds.).

The railroad again strikes the Upper Ludlow shales, rising from a short synclinal, and passes through a section of the Aymestry limestone and a portion of the Lower Ludlow shales, which are overlain, near the eastern entrance to the Ledbury tunnel, by a considerable thickness of red and grey stratified drift derived from Silurian and Old Red deposits (from 13 m. 1144 yds. to 1518 yds.).

This drift appears to me to be one of the most important points with which we have to deal. Bones of *Mammalia* have been detected therein, and amongst them the tooth of *Rhinoceros tichorhinus*. This evidence surely tends to prove that the Old Red Sandstone covered the Upper Silurians of the Ledbury vales as late as the Pleistocene epoch, and that it was removed by the action of Pleistocene waters, which denuded the Old Red Sandstone, and redeposited its débris with the relics of animals that lived on the land.

The tunnel proceeds through the Lower Ludlow shales at 13 m. 1430 yds., and then a fault occurs. The Upper Ludlow shales, with the Aymestry rock, are quarried near Shaft No. 1 of the Ledbury tunnel. The accompanying Section, fig. 6, furnished by Mr. A. Lambert, supplies us with the details of the fault as seen in the tunnel.

Fig. 6.—*Section in Ledbury Tunnel, showing the Fault, at* 13 *m.* 1518 *yds.* By A. Lambert, Esq.



* I have to thank my friend Captain Peyton for directing my attention to this interesting fault.

We descended Shaft No. 2, and examined the tunnel right and left. Shaft No. 2 is in the Wenlock shales; these are seen to pass into the Wenlock limestone (14 m. 406 yds.), which is thrown down, and is horizontal. A glance at the section will explain the extraordinary faulting of the rocks between Shaft No. 2 and the Lower Ludlow rock and the point on the section where the strata incline at an angle of 75°, which dip continues to the western exit of the tunnel, throughout the Lower Ludlow shales, Aymestry rock, Upper Ludlow shales, Downton sandstone, red and mottled marls, grey shales and grits, and purple shales and sandstones, the tunnel ending at the point where the red and grey Auchenaspis-beds pass conformably into the underlying strata*.

The following is the ascending order of the beds observed in the section from 14 m. 957 yds. to 1463 yds.:—1. Aymestry rock with *Pentamerus Knightii*, &c. (10 feet). 2. Upper Ludlow rock with *Chonetes lata*, &c. (140 feet). The Ludlow bone-bed seems to be wanting here. 3. Downton bed, thin (9 feet), with *Lingula*. 4 to 8. Red and mottled marls and thin sandstone (210 feet), with *Lingula* and *Pteraspis*. 9. Grey shale and thin grit (8 feet), with *Cephalaspis* and *Pterygotus*. 10 and 11. Purple shales and thin sandstones (34 feet). 12. Grey marl passing into red and grey marl and bluish-grey rock (20 feet), with *Auchenaspis, Plectrodus, Cephalaspis, Onchus, Pterygotus Ludensis, Lingula*, and a Lituite (?). These pass upwards conformably into a series of red marls, with yellowish grey and pink sandstone containing *Pteraspis* and *Cephalaspis*, and undoubtedly forming the base of the Cornstone-series of the Old Red Sandstone.

With the exception of colour, there is no possible means of drawing any line of demarcation here between the Upper Silurian deposits and the lowest rocks of the Old Red Sandstone. Fossils diminish in number in the Old Red, it is true; but it is evident that this is either owing to the change that occurred in the physical conditions of the sea, or because the chemical condition of the deposits was unfavourable to their preservation. As it is, we have a *Lingula* common to the Downton beds and the Lower Old Red; while Cephalaspidian fishes, beginning in the Silurian (Lower Ludlow), continue upwards into the Old Red.

The section from Malvern to Ledbury is most instructive and most gratifying; for we, who have followed in the wake of Murchison, Strickland, Phillips, and the father of Malvern geology, the present President of the Geological Society (Mr. Leonard Horner), have learned upon how firm and scientific a basis the investigations of these philosophers were founded, and how little we have been enabled to add to the superstructure by later researches.

* See the author's paper on the Ledbury Tunnel, Quart. Journ. Geol. Soc. vol. xvi. p. 193.

Note on the Fossils *found in the* Worcester *and* Hereford Railway Cuttings. By J. W. Salter, Esq., F.G.S.

[In a Letter to the Rev. W. S. Symonds, F.G.S.]

The tunnel through the hill (near Malvern) has given me a better idea of the Woolhope beds than I ever had before. The quantity of fossils is extraordinary. Our own collector, Mr. Gibbs, of the Geological Survey, Dr. R. B. Grindrod of Malvern, and other friends have obtained a great many, and in the most perfect state of preservation. Of Corals there are only a few—the ordinary Wenlock species (for the Woolhope limestone is nothing else than a lower Wenlock rock). Of *Cystideæ* the little *Echinoencrinus armatus* is frequent enough. Trilobites are abundant. *Illænus Barriensis* attained its full size here. The strawberry-headed Trilobites (*Encrinurus*) are in great perfection, also *Cheirurus, Sphærexochus mirus* with its globular head, *Acidaspis, Lichas,* and four species of *Phacops,* including *P. Downingiæ,* the well-known Wenlock and Ludlow form.

The most common shells are, of course, *Brachiopoda,* as in all these muddy sediments. *Lingula Lewisii* and *L. Symondsi* (MS.) are plentiful; *Atrypa,* four species of *Strophomena* (of large size), *Discina, Crania,* three species of *Spirifer,* four species of *Orthis,* six or seven of *Rhynchonella,* just as in the Wenlock limestone: *Pentamerus linguifer* and *P. rotundus* are the most plentiful of all; the latter we have hitherto thought a rare species.

Of the other bivalve shells there are *Cardiola, Mytilus, Pterinea, Avicula,* and *Nucula. Aviculæ,* of two or three species, are the most common.

Spiral shells are not so plentiful. *Euomphalus* and *Cyclonema* are rare. *Bellerophon* is abundant: there are three species, including the great *B. dilatatus* of the 'Silurian System.'

The Cephalopod genera *Orthoceras, Lituites,* and *Phragmoceras* also are rare. Lastly there is *Ischadites,* which I have lately found to be a genus of the sponges!

It will be seen how much this list is like one made from the Lower Ludlow deposits; indeed, in a broad view of the Silurian system, one would not readily separate the Lower Ludlow from the Wenlock rocks.

I have no notes on the Wenlock limestone along this section; nor is it very well developed. I believe it is cut out in many places by faults not entered yet in any map.

Of the Upper Ludlow Rock which lies between the Malvern ridge and Rilbury Camp, it is enough to say that it contains the common species in the usual proportions. When we meet with *Chonetes lata, Orthonota amygdalina, Orthis lunata, Orthoceras bullatum,* and the spiral shells (*Murchisonia,* &c.) with their investing Coral (*Stenopora*), we may be sure that the rest of the Upper Ludlow fossils are not far off; *Serpulites longissimus,* for instance, with a lace-like Bryozoan on its surface, &c.

The Aymestry bands near Rilbury Camp are not characterized by any very peculiar fossils, so far as I know. The Brachiopods are the most common. Instead of the *Spirifer plicatellus* of the Woolhope beds, we have *Sp. elevatus* in abundance. *Rhynchonella Wilsoni* is very plentiful; so are *Lingula Lewisii, Atrypa reticularis*, and *Strophomena Pecten. Pentamerus galeatus* is frequent; but I have not the common *P. Knightii* in my list.

Only a few Univalves and Trilobites are known in this locality.

But if the limestone is poor, the Lower Ludlow shale beneath it is prolific indeed. When I was there, they were bringing up the grey-blue shale full of large *Aviculæ*, of the size and shape of the Pearl-oysters. There was *Pleurorhynchus*, nearly as large as the so-called *Cardium Hibernicum*! Besides a host of ordinary Brachiopods (the list of which would be only a repetition of those of the Woolhope shale) and a very few Corals and Trilobites *, there are here the largest Univalves known in the Silurian rocks. *Pleurotomariæ* of four or five species, some as much as five inches long; of *Euomphalus* three species; very fine Bellerophons, and the common Pteropods; *Orthoceras*, of great size and of many species; and the genera *Phragmoceras, Cyrtoceras*, and *Lituites*.

The profusion of Cephalopods from these beds in Dr. Grindrod's fine collection is wonderful. Among them is a new genus, to be added to the British list, which my friend Dr. A. Fritsch † recognized as one of the familiar Bohemian forms. It looks like a *Lituites*, and would have passed for a new species of it; but there is a slight spirality in the whorls (not so great, however, as in several Bohemian species), which betrays it. It is really a subspiral form belonging to the *Nautilidæ*, and analogous to the genus *Helicoceras* among the Ammonite group. It is 8 or 9 inches in diameter!

I believe that the "Ludlow Bone-bed" is not found in the Tunnel-section. You find it a few miles to the north, at Brock Hill and also at Hales End, overlain by the Downton Sandstone.

The plant which Dr. Hooker described ‡, and for which he now proposes the characteristic name *Pachytheca sphærica*, is the common fossil in the sandstone, and is accompanied, as at Ludlow, by plant-remains and fragments of *Pterygotus*.

Of the "Passage-beds," described by you in your former paper §, I need not say much; but having seen this beautiful section in your company, I may be permitted to observe that I quite agree with your interpretation of it. The little group of olive-coloured shale and grey sandstone in which the Fish-remains are found, is exceedingly like that in the larger section of the same beds at Ludlow. Of the Fish-remains one is identical—the *Cephalaspis Murchisoni*, Egerton; the other is a new *Auchenaspis*, certainly distinct from the Ludlow species. Your section shows just what is wanting at Ludlow—the 300 feet of red marls and sandstones which intervene between these passage-beds and the Silurian rocks, and which definitely shut the former up in the base of the Old Red Sandstone.

* In the fewness of Trilobites this shale differs materially from the Woolhope shale before-mentioned.

† Keeper of the Royal Bohemian Museum, Prague—an excellent observer, and an authority on European birds. We passed three weeks in the Silurian region most pleasantly together.

‡ Quart. Journ. Geol. Soc. vol. ix. p. 12.

§ *Ibid.* vol. xvi. p. 193.

JANUARY 23, 1861.

William Weston, Esq., Birkenhead, was elected a Fellow.

The following communications were read:—

1. *On the* GRAVEL *and* BOULDERS *of the* PUNJÂB. By J. D. SMITHE, Esq., F.G.S.

[Abstract.]

IN the Phimgota Valley (a continuation of the Great Kangra or Palum Valley) the Drift consists of sand and shingle with boulders of gneiss, schist, porphyry, and trap-rock, from 6 inches to 5 feet in diameter. Some of the boulders, having a red vitreous glaze, occur in irregular beds.

This moraine-like Drift lies on the Tertiary beds, which, here dipping gently towards the plains, gradually become vertical, and are succeeded by variegated compact sandstones, gradually inclining away from the plains; next come various slates, at a high angle; and gneissic rocks lie immediately over them.

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2. *On* PTERASPIS DUNENSIS (Archæoteuthis Dunensis, *Roemer*). By THOMAS H. HUXLEY, F.R.S., Sec.G.S., Professor of Natural History, Government School of Mines.

THE fourth volume* of the 'Palæontographica' of Dunker and Von Meyer (1856) contains a memoir on "*Palæoteuthis*, a genus of Naked *Cephalopoda* from the Devonian rocks of the Eifel," by the well-known paleontologist Dr. Ferd. Roemer. The fossil upon which this genus is founded is described as an oval, convex, symmetrical, shield-like body, marked by two diverging longitudinal elevations or keels, and exhibiting on its surface a peculiar ornamentation, consisting of curved parallel ridges, so fine that there are as many as 8 or 10 to a line. All traces of any deeper layer than that which exhibits these ridges had disappeared. In discussing the affinities of this fossil, Dr. Roemer decides in favour of its being the internal shell of a Naked Cephalopod, upon the grounds, first, of its general form, and secondly, of the presence of the diverging keels, in both of which respects he considers the fossil to resemble the internal shell of a *Sepia*. And he adds: "Inasmuch as the fine superficial sculpture is altogether peculiar and different from that of the cuttle-bone, and since, further, the fact that the fossil exhibits such a structure only upon its surface leads one to suspect that it was not a thick ossicle, but thin and horny like that of *Loligo*, and since, finally, its occurrence in so old a formation makes its generic identity with the living genus improbable, it will be justifiable to consider the fossil as the type of a new genus, although its clear definition can

* Page 72, plate 13.

only be rendered possible by the discovery of more perfect specimens, and perhaps of other parts of the animal." (p. 74.)

Dr. Roemer then remarks on the evidence thus furnished of the occurrence of naked *Cephalopoda* at an earlier period than had hitherto been supposed; and, in a note, he refers to Dr. Kner's paper on *Cephalaspis Lloydii* and *C. Lewisii*, disputing the conclusion at which Kner had arrived, that these fossils are remains of Naked Cephalopods, and affirming "that the structure of the shell of these disks is rather that of *Crustacea*, and that their whole external form leads to the supposition that they are allied to such palæozoic *Crustacea* as *Dithyrocaris* or *Pterygotus*." Carefully executed figures accompany the memoir from which these citations are made.

In Leonhard and Bronn's 'Jahrbuch' for 1858, p. 55, Prof. Roemer returns to this subject, in a short "Notice of a second specimen of *Archæoteuthis** *Dunensis*, from the clay-slates of Wassenach, on the Laacher-See," in which specimen the internal structure of the shell is preserved.

"The form and size of this specimen," says Prof. Roemer, "agree essentially with those of the first specimen. Like the latter, it is imperfect, the lower end being absent. The fossil is a coal-black, brittle, horny substance, sharply defined against the slaty grey of the matrix; the thickness of the layer which it forms is about $\frac{2}{3}$rds of a line, as can be distinctly seen by the transversely fractured circumference. The sculpture of the surface is to be observed only over a small space. Here it exhibits the same fine lines as the Daun specimen. For by far the greater part of its extent, the superficial layer of the shell is destroyed, and the internal structure is revealed so distinctly as to make this specimen particularly remarkable. It consists of small prismatic cells, disposed perpendicularly to the surface of the shell. The transverse section of the cells is irregularly hexagonal, or even polygonal; the diameter of the cells is such, that three or four occur in the space of a line, whence the separate cells are perfectly recognizable with the naked eye. The depth of the cells is equal to about one-third of the thickness of the shell. The lowermost layer of the shell appears not to take part in this coarsely cellular structure, but to be much more compact.

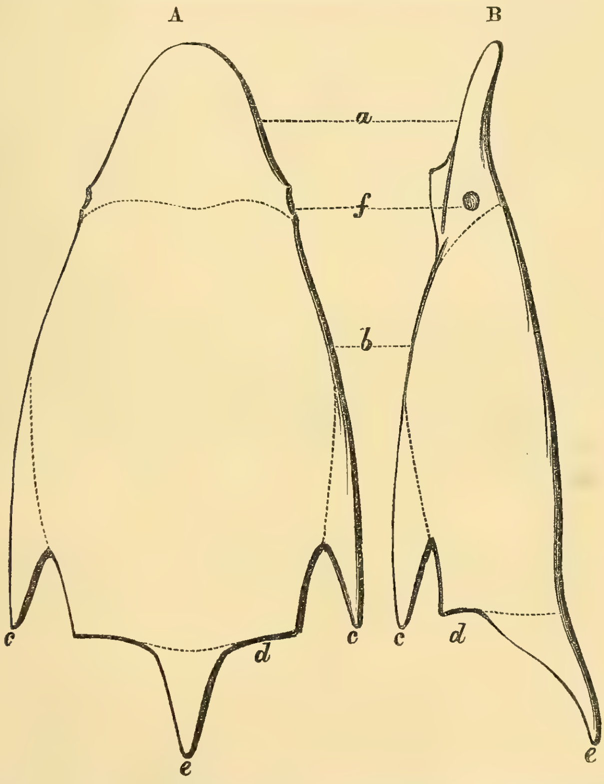
"If this structure be compared with that of the shell of *Sepia officinalis*, L., the close analogy of the two is obvious. Only, in the living genus the cells are much finer and are disposed in numerous thin layers one over the other, whilst in the fossil species but a single such layer is discernible. In any case, this cellular structure of the fossil shell indicates its affinity rather with *Sepia* than with *Loligo*, as I had previously supposed."

The specimen from Wassenach thus described has now passed into the collection of the British Museum; and my friend Mr. Woodward (who had already divined the precise nature of the so-called *Palæoteuthis* in a note to p. 417 of his 'Manual of the Mollusca') having

* In Bronn and Roemer's 'Lethæa Geognostica,' vol. i. p. 520, the name *Palæoteuthis*, having already been employed by D'Orbigny, is given up, and *Archæoteuthis* substituted for it.

called my attention to the specimen, without giving me any information as to its previous history, I at once affirmed it to be a *Pteraspis*,—being led to this determination by the eminently characteristic striation of the outer surface, combined with the no less peculiar polygonal cells of the middle layer*. There is nothing like either of these tissues in any Cephalopod or Crustacean with which I am acquainted—the construction of the cuttle-bone being totally different; and they exist, in combination, in no animal structure which has yet been described, except *Pteraspis*. In form, and in the presence of the diverging ridges described by Prof. Roemer, the fossil perfectly agrees with many of our English *Pteraspides*; and I have therefore no hesitation in expressing the opinion that *Archæoteuthis* must disappear

Diagram of a restored Pteraspis.



a. Snout or rostrum, united with *b*, the shield-like disk. *c*. The cornua of the latter; *d*. its median backward prolongation; *e*. the median posterior spine into which the last is produced. *f*. Orbits or nasal apertures.

* I have carefully described these structures in my memoir "On *Cephalaspis* and *Pteraspis*," Quarterly Journal of the Geological Society, 1858, vol. xiv.

from the list of Dibranchiate Cephalopods, and consequently that the palæontological history of this group cannot, at present, be traced back further than the beginning of the Mesozoic epoch.

The distinction of species among the *Pteraspides* is a difficult matter; and, pending investigations which I have been for a long time making on this subject, I leave open the question whether Prof. Roemer's specimens are or are not types of a new species, which, in the latter case, must be termed *Pteraspis Dunensis*.

In conclusion, I may remark that, as I have already pointed out elsewhere (British Association Reports, 1858), the test of *Pteraspis*, as commonly met with, consists of only a part of the cephalic shield of that singular fish, the whole shield being not a little similar to that of *Cephalaspis*. In *Pteraspis rostratus*, for example, the entire shield has the form indicated by the subjoined outlines, of which A represents a dorsal, and B a lateral view. It consists of a cephalic rostrum (*a*), more or less elongated and pointed according to the species, passing posteriorly into the broad shield (*b*), which (as the dotted lines indicate) is commonly found broken off and alone. When perfect, this is produced laterally and posteriorly into two cornua (*c*), and in the middle line behind passes into a broad prolongation (*d*), which gives rise interiorly to a long, curved, and backwardly produced spine (*e*). Upon each side of the test, where the rostrum joins the rest of the shield, there is a round well-defined aperture (*f*), which may be either the orbit or the nasal aperture.

It is not easy to find an exact parallel for such a cephalic covering as this among existing fishes. *Loricaria*, *Tetrodon naritus*, *Acipenser*, and *Spatularia* seem to present the nearest analogies,—the two former being much more remote than the two latter. In fact, if the bony cephalic shield of the Acipenseroid fishes were ossified in one piece, it would very closely resemble that of both *Cephalaspis* and *Pteraspis*, and would hardly differ more from either than the two from one another.

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3. *On the* "Chalk-rock," *the Topmost Bed of the* Lower Chalk, *in* Berkshire, Oxfordshire, Buckinghamshire, *&c.* By William Whitaker, B.A., F.G.S., of the Geological Survey of Great Britain.

The bed to which I have elsewhere* given the name of "Chalk-rock," I believe to form the division between the Upper and Lower Chalk, and to be the topmost bed of the latter. I have described it as "hard blocky chalk, jointed perpendicularly to the plane of bedding, with lines of irregularly shaped, hard, calcareo-phosphatic nodules, which are green outside, but cream-coloured within." It breaks with an even fracture, rings when struck with the hammer, and is of a pale cream-colour (the nodules being darker than the rest).

* Catalogue of Rock-Specimens in the Museum of Practical Geology, 2nd edition, p. 296.

For some time I thought that this bed had escaped the notice of geologists; but Mr. Prestwich tells me that he has long known of it. It has also been noticed by Mr. Evans, of Hemel Hempstead, and Mr. W. Cunnington, of Devizes. However, I believe that no account of it has yet been published, with the exception of the short description above referred to.

My own observations have been confined to the counties of Wilts, Berks, Oxon, Bucks, and Herts—that is, to the northern side of the western part of the London Basin,—in which area I found that the Chalk-rock reaches its greatest thickness to the west, gradually thinning eastwards.

I have found but few fossils in the Chalk-rock; but Mr. Evans most kindly sent those that he had collected (near Boxmoor) to the Museum of Practical Geology. They have been determined by Mr. Etheridge, and they make up the greater part of the following list:—

Fossils of the "Chalk-rock."

Baculites.
Nautilus.
Rhyncholites (of Nautilus).
Turrilites.

———

Trochus?
Turbo?

———

Inoceramus.
Pachymya?
Spondylus latus.
Sp. spinosus.

———

Rhynchonella Mantelliana.
Terebratula biplicata.
T. semiglobosa.

———

Parasmilia.

———

Ventriculites.

In Wiltshire I saw only one section of the Chalk-rock, not having time to search for others; this, however, showed a far greater thickness of it than I have elsewhere seen. It is in a cutting on the turnpike-road leading up the chalk-escarpment that forms the northern side of the Pewsey Valley, nearly four miles S.S.W. of Marlborough. The Chalk-rock is cut into near the top of the hill; and the following alternations may be seen in it:—

		ft.	in.
Nodules, with a little cherty flint at the top in parts; Hard rocky chalk	about	3	3
Nodules; Hard chalk	"	2	3
Nodules; Hard chalk; Thin line of nodules; Hard chalk	"	2	4
Nodules; Hard rocky chalk; Marly seam; Hard chalk	"	3	4
Nodules	"	0	2
		11	4

As the beds below the last line of nodules were hidden by fallen rubbish, I could not see the full thickness of the "rock." The beds of nodules are two or three inches thick.

Working eastwards, the next place at which I have seen the Chalk-rock is in the neighbourhood of East Ilsley, in Berkshire, where, indeed, I first noticed it. Here its thickness is not much over 4 feet.

About half-way between Pangbourn and Bassildon, in a large pit on the Oxfordshire bank of the Thames, it is seen to be about 6 feet thick; and in the neighbourhood of Henley-on-Thames it is about 4 feet. At this last place, the Chalk-rock and the Lower Chalk occur as an inlier, being surrounded on all sides by Upper Chalk. There are three good sections on the northern side of the Thames between Henley and Medmenham. In these, as well as in the section above Pangbourn, its position in the Chalk is well shown. It forms an exact line of division between the Upper Chalk (with flints) and the Lower Chalk (without flints),—there being generally a bed of flints lying on its upper surface, whilst there are none either in or below it, with the following exception, which does not in any way disprove the rule. In a chalk-pit just above Greenland Lodge, near Henley, there is a section across a small fault, from which, below the Chalk-rock, proceed two highly inclined fissures, some feet in length, but not more than a quarter of an inch broad; each of them is filled with a line of flint, which must clearly have been deposited from some siliceous solution that found a channel down the fissures, and which must therefore be of later date than those fissures. These two lines of flint have no relation to the beds of flints in the chalk above the "rock," but are inclined at a high angle to the line of bedding.

Still working eastwards, the Chalk-rock may be occasionally seen along the chalk-escarpment, at no great distance from the top, and also on the flanks of the main valleys running at right angles to the strike of the Chalk (and differing from the lesser valleys, which are dry, in containing streams).

As the dip of the Chalk is not much greater than the fall of these valleys, the Chalk-rock does not disappear along them for many miles inland from the escarpment. Thus, along the Loudwater Valley it occurs as far south as Wycombe Marsh; in the Misbourne Valley it reaches to a point a little below Amersham; along the Chess Valley, to nearly three miles below Chesham; and in the Berkhampstead Valley to some spot between Boxmoor and King's Langley.

Near High Wycombe, and to the east of that town, the Chalk-rock loses its hitherto well-marked jointing, and breaks up into comparatively small pieces. In the neighbourhood of Wendover, Amersham, and Berkhampstead, its thickness has dwindled down to 2 or $1\frac{1}{2}$ feet; but on the hills to the south-east of the first place there are two beds of it, separated by a few feet of chalk.

The last section of the Chalk-rock that I saw was in a pit near the Boxmoor Railway-station, where for the first time I noticed beds of flints below the rock. Of these I saw but two; and in each the flint-nodules were widely separated: it is possible that here also there may be a second bed of the "rock" lower down. Besides the sections that I saw, I also often heard of the occurrence of this bed in well-sinking. Where it is thick, the well-sinkers are obliged to blast it, on account of its hardness.

Where there are good clear sections, as near Henley, its upper boundary will be seen to be sharply defined, the lower one not; so that I should take it to belong to the Lower rather than to the Upper Chalk. The few fossils that have been found in it bear out this view.

In the parts of the chalk-country of Surrey and Kent known to me, I have not noticed the Chalk-rock; but my friend and colleague Mr. Drew tells me that he has seen, in the former county, a bed that seems to be like the Chalk-rock of Bucks, Berks, &c., and in the same position. It may be seen on the flank of the chalk-escarpment in the large quarries near Guildford, and in others between Dorking and Reigate (north of the word "Betchworth" on the Ordnance Map), where it is about 25 feet thick; and also in the valley along which the Caterham Branch-Railway runs, at the Rose and Crown, about four miles north of the escarpment. The following section taken at this last place has been given me by Mr. Drew:—

Reconstructed Chalk........................	4 or 5 ft.
Chalk with flints	about 25 „
Chalk with nodular structure and a few scattered flints (Chalk-rock?)	„ 25 „
Chalk without flints	„ 25 „

From the above, it is clear that the bed is very thick about here*.

From the account of the chalk-cliffs near Dover, given by Mr. W. Phillips, in the 'Transactions' of the Society†, I cannot clearly make out its presence there. If it be present, it must be in great thickness.

The "Chalk-rock," should it prove to be the topmost bed of the Lower Chalk, as it is in the counties of Berks, Oxon, and Bucks, must have some influence on our notions as to the extent of country taken up by that division of the Chalk. In the above-named counties the Lower Chalk forms nearly the whole of the great escarpment, not being covered by the Chalk-with-flints until within a short distance from the top, except at the highest points of the range; runs along the main valleys for eight, ten, or twelve miles from the escarpment; and, according to well-sections in brick-yards, is but from 40 to 80

* Mr. Drew has lately revisited the chalk-country between Farnham and Guildford, and he tells me that the Chalk-rock is about 25 feet thick in that neighbourhood also.

† 1st Series, vol. v. p. 16, &c.

feet below the surface for a considerable distance from its outcrop*. As in the counties in question the Upper Chalk is not far short of 300 feet in thickness, and sometimes quite that, it is clear that the topmost beds of the Chalk do not generally occur either on or near the escarpment, but that they have been denuded. The Chalk-rock will serve as a datum for the measurement of the extent of this denudation.

There are two more points that may be noticed in connexion with the Chalk-rock. To the north and north-west of Marlborough, the Upper Chalk has an escarpment of its own, quite distinct and separate, and often at a considerable distance, from that of the Lower Chalk, as noticed by Mr. Aveline†. May not this be owing to the Chalk-rock being there very thick, as there is every reason to suppose is the case? Further eastwards, where the Chalk-rock is thinner, the two escarpments generally merge into one.

In parts of the South of England there are flints from the top to the bottom of the Chalk. I do not know whether it is supposed that this flint-bearing Chalk represents both the Upper and Lower Chalk of other parts, or the former only. The occurrence of the Chalk-rock might set at rest the question whether the Upper Chalk only is there present, or whether the Lower Chalk is flint-bearing. The former case would imply an overlap between the Upper and Lower Chalk.

Postscript.—Since this paper was read, Mr. Prestwich has told me that he has seen the bed in question on the top of the chalk-hills between Calne and Marlborough Downs; that it was found in a well at Harpenden, near St. Albans; that it has been noticed by Mr. Bensted and others on Kit's Cotty Hill, near Maidstone (where it is but 2 or 3 feet thick); and that the nodules in it have been found to contain ten per cent. of phosphates.

A more detailed account of the sections of the Chalk-rock in Oxfordshire and Berkshire will be given in a memoir (shortly to be published) illustrating Sheet 13 of the Map of the Geological Survey; and those in Buckinghamshire will be noticed in a memoir (now in progress) to illustrate Sheet 7.

* I find that Mr. Godwin-Austen has noticed the extent to which the chalk-escarpment of Berkshire consists of Lower Chalk. He says, "the highest point, Uffington Camp, appears to rise no higher in the series than the Chalk-without-flints." (Quart. Journ. Geol. Soc. vol. vi. p. 461.)

† See Memoir illustrating Sheet 34 of the Map of the Geological Survey of Great Britain, p. 37.

February 6, 1861.

William Rutherford Ancram, Esq., 75 Inverness Terrace, Kensington Gardens, and Thomas William Jeffock, Esq., C.E., Woodside, Sheffield, were elected Fellows.

The following communication was read:—

On the Altered Rocks *of the* Western Islands of Scotland, *and the* North-western *and* Central Highlands. By Sir Roderick I. Murchison, D.C.L., V.P.G.S., F.R.S., &c., and Archibald Geikie, Esq., F.R.S.E., F.G.S.

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Introduction.—In former memoirs upon the crystalline rocks of the north of Scotland, read before this Society, it was shown by one of us, that in the county of Sutherland, in addition to the existence of a fundamental gneiss and an unconformably superposed Cambrian sandstone, there is a conformable ascending series, from certain Lower Silurian quartz-rocks and limestones, up into a group of micaceous and gneissose schists. It was also pointed out, in a general sketch-map of the Highlands*, that the order thus observable in

* In perusing this Memoir, the reader is referred to the geological sketch-map of the Highlands previously published in Quart. Journ. Geol. Soc. vol. xv. pl. 12. That map, suggestive of that geological order in the Southern Highlands which we have since worked out, will speedily be followed by a general sketch-map of all Scotland, with illustrative coloured sections, in which the correlation of the stratified rocks of the Highlands with those of much less altered characters in the South of Scotland, and containing Silurian remains, will be for the first time explained by ourselves.

the north-western regions of Scotland probably extended southwards across the mountainous tracts to the south of the Caledonian Canal. But this application of the classification of the rocks of the north-west was based on general observations only of earlier years; and a more exact survey was called for before it could be held as proved that the great mass of the Scottish Highlands displayed the same order of succession as had been demonstrated to exist in the north-western tracts.

It was also necessary to trace the development of the Sutherlandshire series to the south-west, through Ross-shire, so as to complete the base-line from which the rest of the Highlands should be worked out in detail.

For this purpose we devoted two months of the last summer to an examination of the Ross-shire district and the region southwards to the Highland border, including the islands of Lewis, Skye, Islay, and Jura. The results of this survey, completely confirming our previous views, are laid before the Society in the present memoir.

I. Range of the Laurentian or Older Gneiss in the Hebrides and North-Western Highlands.

Lewis and Harris.—As announced in previous memoirs, the greatest spread of the Older or Laurentian Gneiss is seen in the Long Island of the Hebrides, by much the larger portion of which is called "the Lewis*," the lesser or southern part being "the Harris."

In both these tracts the mineralogical character of this older gneiss, and its numerous contortions, have been so well described by Macculloch, that little remains to be said on those heads by others. That author has, however, omitted to state that the usual and dominant direction of the strata is transverse to the elongated form of this island; for, whilst the geographical axis of the whole, as seen in any map, is from N.N.E. to S.S.W., the normal strike of the beds of gneiss is from S.E. to N.W., or across the island. The traveller who has not much time at his disposal may convince himself of this fact in a few hours by examining the rocks which rise up to the west of the Port of Stornoway. If he should have sailed from the opposite mainland, and have there observed that on the shores of Lochs Maree, Gairloch, and Torridon the Laurentian gneiss has a persistent strike from N.W. to S.E., with dips to the N.E. and S.W., he will find precisely the same phenomena in the Lewis.

Whether he examines the various points of rock—so well exposed in the pleasure-grounds of Stornoway Castle, and particularly those which have been cut through by Sir James Matheson on the banks of the torrential river Creed, or the sea-cliffs of the headlands on the east—or should cross the peat-covered moors, to the western shores and the interior, to Morsgail or to Soval, or even should extend his researches into the Harris beyond Athline,—he everywhere meets with the same phenomenon of a prevalent strike from

* Pronounced "Lews."

N.W. to S.E. with countless undulations, and decided inclinations at all angles, both to the N.E. and S.W.

In saying that the strike is from N.W. to S.E., it must be added that this direction sometimes varies slightly to the N. and S. of N.W. and S.E.; but the normal strike is precisely that which prevails also in rocks of the same mineral character on the western shores of the mainland in Ross-shire and Sutherland.

As before shown*, the strike of this old or bottom gneiss is therefore at right angles, or nearly so, to the N.E. and S.W. direction of all the superjacent crystalline rocks of the mainland, including the quartz-rocks and limestones, and all the overlying formations. In no part of the Lewis is this dominant strike better exhibited than in the hilly deer-forest of Sir James Matheson at Morsgail. There, and adjacent to the shooting-lodge, the gneiss is admirably exposed in several openings, and consists of infinite alternations of highly-inclined dark hornblendic and whitish quartzose laminæ, which beds, as exposed on the sides of a burn, are rolled over and over into numerous contortions, with dips both to the S.W. and N.E. These strata are every here and there diversified with protrusions of highly crystalline hornblende-rock, in parts a greenstone, which rise in large round masses, or are distributed in geodes and layers. The abundance of iron in this rock occasions the decomposition of its surface into holes and irregular cavities; and numerous masses so honey-combed strew the edges of Loch Morsgail.

In the hills of Scalaval, all the gneiss, whether quartzose, hornblendic, or felspathic (more rarely micaceous), has again the direction from N.W. to S.E., or to points slightly deviating therefrom. The same is seen in the mountainous masses along the shores of Loch Langabat, where the N.E. or S.W. inclination of the beds is strongly contrasted with the great transverse fissure occupied by that long sheet of fresh water, which, on the contrary, is parallel to the geographical axis, *i. e.* N.E.–S.W., and therefore nearly at right angles to the strike of the ancient strata of gneiss. In short, the phenomenon of the trend of the hills and valleys on the actual configuration of the surface being transverse to the original direction of the strata is as strikingly exemplified in the Lewis and Harris as it is in the Harz and other masses of rock on the continent of Europe†.

Such contrasts between the original direction of the layers of deposit and the geographical outline of the islands are also strikingly displayed where the low and moss-covered hills of the Lewis rise into the mountains of Harris.

Passing from Loch Seaforth into the rocky glens of Vickadell and Scaladell, and under the frowning steeps of Craig Arig, the Clishan, Moolan Gorran, and Scorse Scaladell, the highly crystalline gneiss (here quartzose and grey) still ranges from N.W. to S.E., and dips either to the S.W. or N.E.‡

* Quart. Journ. Geol. Soc. vol. xvi. p. 216.

† See Quart. Journ. Geol. Soc. vol. xi. p. 449, and 'Siluria,' 1859, p. 414.

‡ These glens of Harris, radiating from lofty and steep mountains, afford splendid evidences of glacial action, their mouths and flanks being studded with

In numerous places the strata are strikingly interfered with by intrusions of granite, as well as by hornblende-rock and greenstone. In one tract only, however, that fell under our observation does granite occupy so considerable a surface as to be entitled to a place in our forthcoming sketch-map of Scotland,—a feature unnoticed by Macculloch and other geologists. This mass of granite comes out at Dalbeg, on the west coast of Lewis. There, whilst the hills of Baravas range in geographical outline from N.E. to S.W., the granitic ridge is protruded from them to the coast on the north-west, and is thus shown to conform in its direction to that of the main masses of the ancient gneiss. This granite is coarse-grained and of various colours (though the prevailing tint is red), and, containing felspar, quartz, and mica, is entirely free from hornblende. As veins of this granite traverse the gneissose rocks, it is evidently of later origin than the deposition of the gneiss.

Besides the usual varieties of gneiss, whether consisting of layers, of quartz and felspar with mica or with hornblende, white hyaline or flinty quartz is occasionally seen in the form of layers of both pink and white colours, sometimes presenting the appearance of having been injected amid the layers of gneiss, in the same manner as the numerous granitic veins. In some places the laminated and bedded gneiss has undergone great decomposition, as at Garrabost, in the promontory of Eye. There, near the entrance of the Chemical Works * under the direction of Mr. Paul, the gneiss, consisting of fine layers of quartz, felspar, and mica, has been so affected by atmospheric influences as to exhibit the following appearances. The felspar having decomposed and passed into heaps of clay, the quartz-grains and the flakes of mica remain in the form of a framework which might pass for an incipient band of soft ordinary micaceous sandstone formed on the shore of the present sea. Again, the felspar of the old gneiss contains a considerable admixture of lime, and hence it affords, on decomposing, not merely good clay, but much carbonate of lime in solution. Thus detached fragments of the overlying conglomerate, of which we are about to speak as seen on either side of the bay of Loch Tua, over which the water trickles down from the decomposing gneiss to the shore, as well as the pebbles and shells of the present bay, are bound together on the slopes of the cliffs and on the sea-shore by the cementing carbonate of lime, and form a hard calcareous grit and conglomerate. Before we quit the consideration of this fundamental British rock, as seen in the outer Hebrides, we would beg our readers to consult the various chapters of Dr. Macculloch in which he dwells upon the dull and monotonous character of the gneiss in all this range of islands, as contrasted with the descriptions of the same author of his so-called gneiss of interior portions of the mainland. For, although he grouped various and dissimilar rocks in the family of gneiss, and gave no proofs of

stupendous erratic blocks. The hills of the Lewis are too low to have been the seats of glaciers: and on that northern portion of the island erratics are scarcely to be discovered.

* For the distillation of bitumen from peat.

their true succession, he had, even in his day, so faithfully delineated the essential mineralogical distinctions between the gneiss of the Western Isles and that of large tracts of the mainland on the east, as to prepare the way for those who, like ourselves, have worked out the proofs of a clear order of superposition. Combining these proofs of succession with the manifest distinction in the lithological structure of the two classes of rock, we are of opinion that no geologist can confound the Laurentian or fundamental gneiss with the so-called gneiss of the superior crystalline schists, which, instead of being a massive hornblendic and granitoid rock like the first-formed, is, on the whole, a flag-like, micaceous, and quartzose deposit of very different characters.

Although we have not, like Macculloch, traced the persistence of this same Hebridian or Laurentian gneiss through all the isles where it abounds, we have observed it in the Isles of Rona and Raasay. It forms the whole of the former island, and the northern end of the latter at Castle Brochel in Raasay; it is overlain by Cambrian shales and sandstones, which, towards the south end of the island, are replaced by coarse conglomerates, well seen in the watercourses south of the road from Raasay House* to the eastern shore, as well as along the cliffs of the opposite Island of Scalpa†.

Cambrian Conglomerate of the Lewis.—With the exception of superficial accumulations of sand, clay, or pebbles, the island of Lewis offers nowhere any deposit overlying the ancient gneiss, except an old conglomerate composed exclusively of fragments of that rock, associated with a few sandy layers. These beds are exhibited at intervals on both sides of the Bay of Loch Tua. They are made up of pebbles of the older gneiss, varying from the smallest size to boulders larger than any among the Cambrian rocks of the mainland: their chocolate-red colour, precisely that of the sandstone strata of Sutherland and Ross, is probably due to the extensive decomposition of the iron of the hornblendic masses which prevail in the subjacent gneiss.

As this conglomerate is unknown in the Lewis, except upon the headlands and bays east of Stornoway ‡, where it is exactly opposite to the Cambrian conglomerates and sandstones of the mainland of Ross-shire, which also are formed exclusively out of the subjacent bottom-gneiss, and dip away to the west, as if passing to the Lewis,

* Mr. Geikie has explored and mapped the geology of Raasay, with reference especially to its Oolitic strata, and hopes soon to be able to lay the results before the Society.

† In a new sketch-map of Scotland, now in course of preparation, we have represented the Isles of Tiree, Coll, and Iona as composed essentially of Laurentian gneiss, not only because they are identified with the gneiss of the Long Island by the minute description of Macculloch, but also from the independent testimony of the Duke of Argyll, who lately visited his property in Tiree. Thoroughly well acquainted with the character of the so-called gneiss of Argyllshire, where granites and intrusive rocks equally abound as in the Hebrides, his Grace so recognized the striking lithological distinction between the two classes of rock, that he declared to us that no such gneiss as that of Tiree exists on the mainland.

‡ The Lighthouse and part of Stornoway stand on this conglomerate.

there can be little doubt, in our opinion, that the Lewisian beds formed the western or shore-side of an extensive trough of a deposit of the same age, the central portions of which are covered by the waters of the broad channel of the Minch.

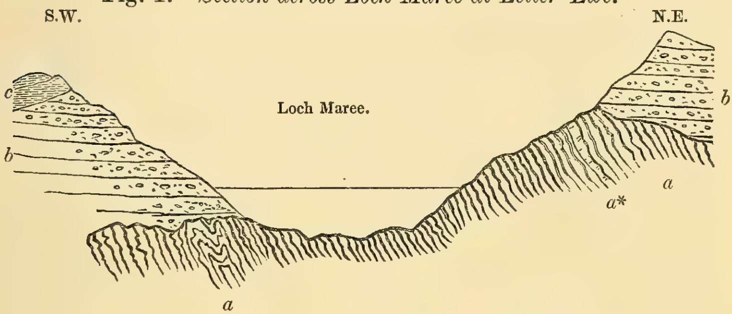
On the mainland, indeed, there are decisive proofs that these sandstones and conglomerates are of Cambrian age, because they are clearly surmounted, as shown in previous memoirs, by strata containing Lower Silurian fossils. In the Lewis, however, where there is no upward sequence, the inference that they are of the same remote age must rest upon the fact of their being made up exclusively of the Laurentian gneiss, and on the appearance they present of having been a portion of the same great range of red and chocolate-coloured sandstones which occupy the opposite headlands of Ross and Sutherland. At the same time it is right to state that the sandy beds intercalated in the conglomerates of the Stornoway headlands are so infinitely less coherent than the red sandstone of the mainland (for the thin courses of sand in the Lewisian beds are rarely in the form of solid stone, but have rather a soft marly character) that some doubt must always remain as to the true age of these insulated deposits. It is the more essential to enter this *caveat*, because there are red conglomerates at various places along the west coast of Scotland (as, for example, at Oban), the ages of which are also incapable of rigorous demonstration, from the absence of any overlying deposits.

The conglomerate of the Lewis is cut through by dykes of greenstone, which have a direction from N. by W. to S. by E., and are well exposed on the northern face of the headland of the Eye. Containing some olivine, these dykes of greenstone have produced a marked effect on the conglomerate through which they cut, as seen on the sides of the cliffs. Flanked on either side by a thin "Sahlband" of Lydian stone which separates the greenstone from the conglomerate, the latter is for a yard of a whitish colour,—the red colour of the rock, as due to the presence of iron, having been driven off.

Laurentian Gneiss of the Mainland in Ross-shire.—Descriptions have previously been given of the character of the older gneiss of Sutherland, where it usually forms low headlands on the sides of deep bays, and is unconformably surmounted by mountainous masses of Cambrian Sandstone. The same rocks, extending southwards along the western shore, expand largely in Ross-shire, as exhibited in Gairloch and on the sides of Loch Torridon, as well as on the eastern side of the long freshwater Loch Maree. On the right bank of Loch Maree this gneiss contains both limestone and ironstone, which occur in bands regularly interstratified, and which have the normal strike of these ancient beds, as in the outer Hebrides. This strike from N.W. to S.E. is therefore parallel to the great depression occupied by the water of Loch Maree. In no portion of the North-western Highlands is there a tract which more completely exhibits the entire independence of this Laurentian gneiss of all those overlying deposits, also termed gneiss, with which Prof. Nicol has recently sought to identify it, both in his Geological Map of Scotland and in his memoir read before the Geological Society. We therefore call special attention, not only to the N.W. strike of the beds of this fundamental rock, as contrasted with the north-easterly strike of the eastern rocks, but also to the marked distinctions in lithological composition between it and any of the overlying masses.

The older gneiss which ranges along the north-eastern side of Loch Maree, and rises in some places to several hundred feet above the water, is unmistakeably the same hard, massive, and highly crystalline rock as elsewhere in the outer Hebrides and the coast of Sutherland. At several places it exhibits subordinate layers of fine schistose limestone, which above the House of Letter-Ewe is encased in dark-grey gneiss (fig. 1), occasionally schistose, with white quartz-

Fig. 1.—*Section across Loch Maree at Letter-Ewe.*



a. Gneiss. *a**. Schistose limestone.
b. Cambrian sandstone and conglomerate.
c. Quartz-rock.

veins. This limestone, which has been quarried by the proprietor on both sides of the torrent Fuolish, is for the most part a whitish or cream-coloured, scaly, fracturing rock, and, though here and there mixed with earthy greenish schist and gneiss, it is in parts a brilliant snow-white saccharoid marble. Whether, therefore, we look to its composition, or to that of the enveloping gneiss, this limestone is as distinct as possible from the dull grey-and-white limestone, which, subordinate to the quartz-rock and overlying series of strata, has also a totally discordant direction. The one rock must therefore have been formed long ages before the other.

In the sequel we will endeavour to show, when explaining the details of another section, that it is physically impossible that this Laurentian gneiss of Loch Maree should, by any great upheaval, be so placed as to lie conformably upon Lower Silurian limestone and quartz-rock to the west of Kinloch Ewe. In the mean time we would point to the geological map of Professor Nicol, to indicate a serious *erratum* as to the direction of this limestone, which occurs in the gneiss of Loch Maree. It is therein represented as directed from N.E. to S.W., and therefore as passing across to the S.W. side of the loch*. If this were correct, some persons, who have not visited the

* Prof. Nicol has here, and in many other portions of his map, followed Macculloch.

tract, might be led to believe that this lower gneiss, being parallel to the gneiss on the S.E., was truly part and parcel of the same series of deposits as the rocks on the S.E.; for in that case they would only have to imagine the intervention of a stupendous fault. But the plain fact entirely overthrows this hypothesis. The older or gneissose limestone trends rectangularly to the direction which has been assigned to it, and hence it cannot (being a true bed) traverse the loch as represented. In fact, there is no trace of limestone on the left or S.W. bank of Loch Maree, though, at some miles distant, in Gairloch, and, again, subordinate to the north-westerly strike of the Laurentian gneiss, another thin course of limestone has been detected, and partially worked. In short, between Loch Maree and the sea-board at Gairloch, wherever the fundamental gneiss is uncovered in low masses beneath the superjacent masses of Cambrian sandstone (the highly-inclined strata being admirably exposed in the gorge wherein the River Kerry forms the picturesque Falls of Andresy), the persistence of the N.W. strike is clearly maintained.

Again, near Shieldag, and at the headlands on either side of the mouth of the maritime Loch Torridon, as seen at the Point of Grabeg, and extending up the loch westwards, the Laurentian gneiss has the same north-westerly strike as in Loch Maree and Gairloch, in Sutherland, and in the Lewis, and is seen dipping sharply to the N.E. wherever its eroded edges thin off into low hummocks under the stupendous and mountainous masses of the Cambrian sandstone forming the rugged overhanging cliffs on both shores of Loch Torridon.

In this district the underlying massive gneiss is perforated by numberless intrusions of granite, as in the fiords of Sutherland, and is in itself undistinguishable from the rocks of the same age which range from Cape Wrath to Loch Inver*. It is therefore, we repeat, most easily distinguished by its general aspect and structure from the overlying flag-like rocks with which it has been confounded.

II. Cambrian Sandstone and Conglomerate.

In former memoirs these rocks, particularly as they occur in Sutherland, have been so fully described, whether, as formerly, under the misnomer of Old Red Sandstone, subsequently by Professor Nicol as simply Red Sandstone, or by one of us as Cambrian, that on this occasion we need only advert to them in their prolongation through Ross-shire from the north of Loch Broom on the N.N.E. to Applecross on the S.S.W.

In this tract these rocks range from about sixty miles in length, and over an average width of not less than twenty miles, and form clusters of mountains varying from 1500 to 3500 feet above the sea, their lowest beds being seen in numerous places to repose on the Laurentian or fundamental gneiss. The promontories on both sides of the marine Bay of Gairloch, as well as the noble mountains of Applecross, consist of slightly inclined masses of this chocolate-coloured sandstone, which there dip very gently seawards from off the older gneiss, or to the W.N.W. In following these same rocks

* Quart. Journ. Geol. Soc. vol. xv. p. 361; and vol. xvi. p. 218.

towards the interior of Ross-shire, their lower beds, particularly on both sides of Loch Maree, either consist of conglomerates made up exclusively of the gneiss on which they rest, including much white quartz and felspar, or they are very coarse grits, which pass upwards into the fine siliceous chocolate-coloured sandstone. This junction of the lowest beds of the Cambrian is well exposed on the N.E. side of Loch Maree, on the sides of the Haasach Stream, and particularly at the base of the lofty mountain Sleugach, which is essentially a Cambrian rock. There the fundamental gneiss, in low headlands, dips S.W. at 70°, and the overlying sandstone, at 10° to 12°, to the E. by N.

Again, on the opposite or western side of Loch Maree, where the red and chocolate-coloured sandstone, covered by gorgeously rich thickets of fern, heather, and grand old Scotch-firs, approaches the older gneiss of Gairloch on which it rests, the basement-strata become first coarse and gritty, and then form here and there pebbly conglomerates.

From the western shores of Loch Maree this Cambrian sandstone rises into a noble, lofty group, some of the summits of which, being capped by whitish Lower Silurian quartz-rock, have led the natives to style these mountains "Ben Too leach," or "the Grey Heads." Looking from the hills east of Loch Maree to these mountains on the west, which range from Ben Eay by Roostag to Ben Alligen, on the south side of Loch Torridon, the spectator has within his vision massive mountains, whose summits range from 3000 to 3500 feet above the sea. Now, all the strata of this mountain-group, which cannot on the whole be estimated as having a less thickness than 7000 or 8000 feet, and which rest in unconformable positions on the Laurentian gneiss, are on numerous summits capped by unconformable strata of quartz-rock with subordinate limestone. In fact, the Cambrian strata undulate in such slightly inclined positions as seldom to exceed 12° or 15°, whilst the subjacent gneiss and the overlying quartz-rock are frequently highly inclined. These Cambrian rocks, whether inclining gently to the W.N.W. or to the E.S.E., constitute therefore a thick series of intermediate strata, which are quite unconformable both to the rocks beneath and to those above them.

In striking contrast to these unconformities, we shall presently point out that, along a frontier of many miles in length, the geologist has no sooner passed over the fundamental gneiss and the Cambrian sandstone, and marked the transgressive junction of these rocks with each other and also with the overlying quartz-rock, than he meets thenceforward, in all the great overlying crystalline masses, with a perfect conformity of direction of all the strata to each other; and that (omitting a few spots where local dislocations have occurred) there exists a perfect ascending order from the Lower Silurian quartz-rocks and limestone into younger and higher masses of micaceous, quartzose, and chloritic rocks (including occasionally a younger gneiss), not merely in the North-western Highlands, but also in the Southern Highlands, including the Isles of Islay and Jura, and the counties of Inverness, Argyll, Perthshire, &c.

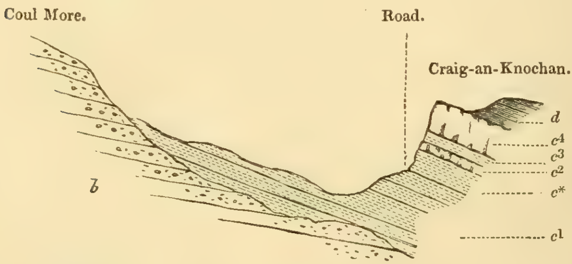
III. Succession of Lower Silurian Quartz-rocks, Limestones, and Schists.

1. *Sutherland to the Isle of Skye.*

In a former paper, the succession of Lower Silurian quartz-rocks and limestones upon Cambrian sandstones was traced to the southern confines of the county of Sutherland. In the present memoir we propose to take up the lines where they were then left, and trace them southwards through Ross-shire into Skye.

Craig-an-Knochan.—The enormous escarpment of limestone that ranges southward from Inchnadamff becomes less in its southward progress, owing to a gradual thinning away of the calcareous strata. The general succession, however, remains the same. These facts are well shown at the watercourse which divides the counties of Sutherland and Ross, where it pours over the cliff of Craig-an-Knochan. This cliff, here from 60 to 100 feet high, is formed by the escarpment of the limestone, and shows along the whole course a clear section of the strata. The road which skirts its base runs upon the white quartz-rock that stretches westward, across a mossy valley, and then ascends for some way up the sides of Coul-more, an enormous denuded mountain-mass of gently inclined Cambrian sandstone. The white quartz-rock is surmounted by brownish beds containing fucoid impressions, these again by a band of white quartz-rock, above which comes a thick white limestone reaching to the summit of the cliff, where it begins to slope below quartzose

Fig. 2.—*Section at Craig-an-Knochan.*



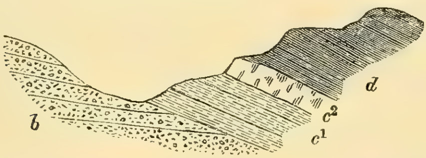
b. Cambrian sandstone and conglomerate. c^1. Quartz-rock. c^*. Fucoid-bed. c^2. Limestone. c^3. Quartz-rock. c^4. Limestone. *d.* Gneissose schist.

micaceous beds, the whole dipping E. or E.S.E. at 10° to 15°. The details, of course, vary considerably even in the course of a few yards; but the general order remains the same, the limestone being regularly intercalated between a series of white quartz-rocks below, and a set of quartzose schists (= the Upper Gneiss of previous papers) above.

This order continues to be observable until the road deflects a little to the south-east, crossing the limestone, which then plunges below a series of lonely mountain-tarns, and is not again seen until we reach Drumdrynie, about a mile and a half to the south. The schistose series which covers the limestone, however, is well exhibited along the roadside. It consists of quartzose, micaceous, fissile, and flaggy strata, to different parts of which the terms quartz-rock, grit, or mica-schist might be correctly applied. The general dip is a gentle one to the E. or E.S.E.; and as the road quits the lochs and winds along the west side of a broad valley, the strata can be seen to the east, rising terrace over terrace, with the steep fronts facing the west, and the sloping declivities dipping eastward, like their component strata.

Drumdrynie.—At Drumdrynie Cottage, which lies on the west side of the road between Inchnadamff and Ullapool, the limestone again appears. Here, too, it is clearly interpolated between a lower quartz-rock and an upper quartzo-micaceous series. It is seen on the gentle ridge behind the cottage; thence it descends, crosses the stream and the road, and keeps along the roadside as a terrace or escarpment similar to that of Craig-an-Knochan, but greatly lower. The succession can be studied with advantage in the stream, and also along the roadside for fully two miles, where the following section is observable:—

Fig. 3.—*Section South of Drumdrynie Cottage.*



b. Cambrian sandstone and conglomerate. *c*[2]. Limestone.
c[1]. Quartz-rock. *d.* Gneissose schists.

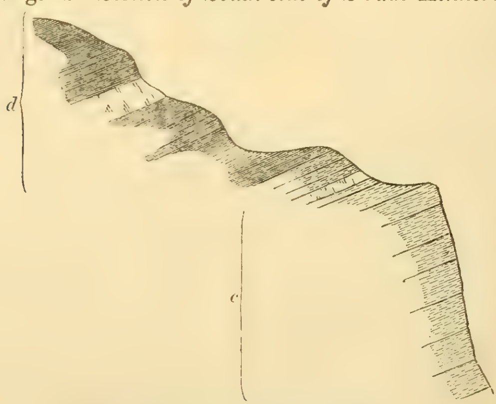
The strata which repose upon the limestone, when traced across the hill to the farm-house of Langwell, are seen to be frequently twisted into crumpled laminæ, often highly micaceous. They graduate upward into dark-grey or greenish flaggy beds, which at one time might be called gneiss, at another mica-slate, at a third clay-slate; but by far the most abundant material in their composition is quartz. They are well exposed at the head of Strath-Kennort, a short way above Langwell, where the river bursts through a narrow gorge in some picturesque cascades. The strata here are dark and schistose, with a mass of porphyritic felstone, running parallel to their strike.

Strath-Kennort.—Strath-Kennort is a valley which extends in an east-and-west direction from the maritime loch of the same name to the cascades just mentioned. The limestone, after approaching within a short distance from the north side of the strath, is lost under the herbage, though a quantity of fragments and an old kiln may perhaps indicate its site on that side. On the opposite side, however, it is readily apparent by the bright verdure of the knoll in which it protrudes into the valley.

A small streamlet has laid open the junction of the limestone (which is here of much greater thickness than where last seen) with the superjacent beds. The main mass of limestone is greyish or bluish-white and grey, weathering grey or yellow; but the upper part is white. It is surmounted here by a bed eight to ten feet thick of white quartz-rock, which dips below a series of schistose beds that incline to E. 30° S. at 20°. The band of quartz-rock thickens greatly towards the N.W., and is marked by veinings of serpentine. The schistose series is of various shades of green, grey, or white, micaceous and quartzose, the laminæ being much contorted.

The strike of the strata carries them obliquely up the southern side of the strath; and we can mark that in their progress the limestone rapidly thins off, while its overlying band of quartz-rock thickens in a corresponding way. About a quarter of a mile east of the cascades formed by the descent of the waters from a chain of small lakes into the strath, a fault has thrown the limestone 150 or 200 feet down the face of the cliff. At the top of the escarpment, resting on the great lower white quartz-rock, the limestone is again seen, but rapidly diminishing in bulk, until, in a few yellow knobs half-buried in the long brown bent, we lose trace of it altogether. After a short distance we meet with another band of limestone along with a series of shales and sandstones. The section here displayed is partly obscured by a morass, and partly by a fault, which, however, since it traverses the strike of the beds, probably does not materially affect the order given in the annexed figure.

Fig. 4.—*Section of South side of Strath-Kennort.*



c. Quartz-rock and a band of limestone.
d. Gneissose schists including a bed of limestone.

From the frequent thick covering of peat and heath, it was difficult to determine the course of the limestones. The beds between the seams appeared to grow more calcareous, until the whole became one thick limestone resting on quartz-rock, and dipping below gneissose flaggy beds. This limestone follows a curved, sinuous line across the hilly ground to Loch Auchall, now seeming to disappear beneath the vegetation, and then swelling out again into irregular lenticular mounds and ridges. The curving of the line of strike conforming in great measure to the contour of the ground, shows clearly enough that there is no great line of fault here. The strata dip to the south-east, and unequivocally pass under a superior group of thin-bedded micaceous and quartzose schists.

Before quitting Strath-Kennort, it may be well to mention that this deep valley affords a good illustration of the varieties of form and colour imparted to a landscape by changes in the character of its composing rocks. Standing at the lower opening of the strath, all is sombre and brown. The dull-red Cambrian sandstones, hoary with lichens, project their rounded edges out of a shaggy mantle of dun heather and stunted bent. Further up the glen, however, where the quartz-rock descends upon the slopes, masses of snowy crag stand out from the dull herbage. Beyond this a bright-green knoll, protruding from the brown hillside into the browner valley, reveals the presence of the limestone, while, far away at the head of the strath, dark crags and grey scars, rising terrace over terrace, with still the same dull heath between and above them, show where the upper gneissose beds have begun to set in.

Loch Auchall.—The sections in the deep gorge of the Auchall, from the lake to the sea near Ullapool, afford a clear exposition of the order of succession. They have been well described by Professor Nicol*; and we cannot resist quoting a passage from his memoir. "On the steep slope," he says, "first the limestone crops out, then the serpentine, and above all the gneiss, forming the summit of the hill, where it dips at 10°–15°, S. 30° E., though with slight undulations. The rocks may be traced round the south side of the hill, placing their relations to each other beyond all doubt. A vertical section through the summit would pass in succession through the gneiss, serpentine, limestone, quartzite, and probably the red sandstone."

The limestone in this section has attained a great thickness. We estimated it at somewhere about 500 or 600 feet. The "serpentine" of Professor Nicol deserves some notice. In his section of Loch Broom he has represented this rock as a bed intercalated between the limestone and his "upper gneiss." And this is undoubtedly its true position, although he has subsequently endeavoured to explain away what he at first regarded as "beyond all doubt," by supposing that the "serpentine" has come up in a great line of fissure, and that the "upper gneiss" is not upper gneiss at all, but the old Laurentian rock brought up by a gigantic fault.

The rock, as seen at Loch Auchall, we should call a porphyry, or porphyritic felstone with serpentine. It is disposed in rude beds, under which the limestone dips, and which are ranged in parallel ridges dipping in the same direction with the limestone. Near the

* Quart. Journ. Geol. Soc. vol. xiii. p. 21.

latter rock it is full of green serpentine, some parts of the mass consisting almost wholly of that mineral, which becomes less and less abundant away from the limestone. The chief component minerals of the greater part of the porphyry are pink felspar and semitransparent quartz, the latter occurring sometimes in circular patches. Lastly, at least at one point, the quartz and felspar granules are distinctly rounded, and the rock contains numerous rounded pebbles of quartz and jasper, some of which are as large and round as walnuts. This same rock occurs also on the shores of Loch Broom; and the section there laid open will be immediately described.

The Upper Gneissose series does not immediately cover the limestone, owing to the occurrence of this felspathic rock; while the junction-line is still further obscured by a thick covering of peaty matter. But from the head of the gorge the shelving beds of that series can be seen along the margin of Loch Auchall, having their prevalent easterly dip.

Descending the gorge of the Auchall River by the post-road, we cross the admirable section of the limestone, quartz-rock, and Cambrian sandstones described by Prof. Nicol. That geologist also details the section along Loch Broom; but there are some features in the coast-line which it seems ncessary to describe here.

Fig. 5.—*Section along the North side of Loch Broom.*

a. Gneiss.
b. Cambrian sandstone and conglomerate.
c[1]. Quartz-rock.
c[2]. Limestone.
d. Gneissose schists.
* Serpentinous and felspathic rock containing pebbles of jasper.

Loch Broom.—The town of Ullapool stands nearly on the line of demarcation between the quartz-rock and the subjacent Cambrian sandstones. Following the clear natural section along the high road from Ullapool to the south, we find the quartz-rock in well-marked beds dipping E. 4° to 10° S., at 10° to 15°. Towards its upper part the rock assumes a pink tint in alternate bands of lighter and darker shades. Annelide-burrows are numerous; and it is worthy of remark that the tubes are white in the reddish rock, recalling the aspect of those in many parts of the Carboniferous rocks, where, from an under surface of shale, dark worm-pipes ascend into white sandstone. Alternations of argillaceous shale occur among the quartz-beds; and at the bridge of Ault Corry we meet with the limestone. Here, however, it is only about 10 or 12 feet thick, and dips E. 30° S., at 15° to 20°. It is covered by a bed of what Professor Nicol calls "serpentine or felspar-porphyry," which, in his section of Loch Broom*, is correctly represented as

* Quart. Journ. Geol. Soc. vol. xiii. p. 22.

interstratified between the limestone and a higher micaceous series. He has since endeavoured to invalidate his first impressions of the locality, in order to support a theory subsequently embraced by him, that what he called "upper gneiss" is really the lower Laurentian rock brought up by a great dislocation. To favour this explanation, he now lays stress upon the eruptive character of this porphyry, and seeks to show that it has come up in a line of fracture, carrying up with it the older gneiss. But for this hypothesis, there is assuredly no foundation in the sections so well exposed along the shores of Loch Broom. Prof. Nicol's first reading of the geological sequence, from which he has since so widely departed, is the correct one, and so palpable, indeed, that it could not easily be missed. There are some features of this so-called "felspar-porphyry," however, which deserve special attention, since they bear on the elucidation of the nature and process of the metamorphism of the Scottish Highlands, and were carefully examined by one of us along the sea-margin, the post-road, and the intervening ground.

Where it overlies the limestone, it is a greenish, quartzose, serpentinous rock. Tracing it down to the shore and along the line of low cliffs, we find the serpentine diminish in quantity, its place being taken by pink felspar with a plentiful admixture of quartz-granules. In this part of the rock, small rounded pebbles of red jasper were observed; and a close scrutiny soon showed that such pebbles, along with others of white and pink quartz, were abundant, forming in some places about half of the rock. The weathered surfaces, owing to the wasting away of the felspar, exhibited a closely aggregated mass of small rounded granules of pink and white quartz, which, in not a few instances, were arranged rudely in rows like lines of stratification. Along the shore-line this rock was found to become finer in grain, until it passed slowly into a red sandstone, hardly distinguishable from that of the Cambrian series, save in its paler colour and more metamorphosed aspect. This sandstone is followed by a white quartz-rock very crystalline, and with no perceptible trace of bedding, though clearly itself a bed between sheets of darker material. Above the quartz-rock come greenish felspathic and serpentinous rocks with occasional quartzose patches, the whole very irregular. These are succeeded by a white and greenish serpentinous quartz-rock; and beyond this, the rocks, still serpentinous, shade off into quartzose flaggy beds with a general south-easterly dip. These range south-eastward for several miles with the same general inclination, and are in every respect identical with the quartzose and schistose series already described as overlying the limestone from Assynt to Loch Auchall.

This intercalated band of so-called "felspar-porphyry" certainly does not interfere with the regularity of the order of succession. We do not regard it as igneous at all, further than the gneiss is igneous. On the contrary, the greater extent of alteration towards the limestone, the larger amount of serpentine in the proximity of that rock, the abundant rounded granules and pebbles of quartz and jasper, the passing of the pebbly zone into sandstone, and of the quartz-rocks into a quartzose flaggy series, seem to us facts which go far to prove that this "serpentine or felspar-porphyry" is in reality a highly metamorphosed band of felspathic grit,—the superior degree of metamorphism being due to the existence of the limestone, and possibly also to the large amount of felspar in the original rock.

It may be noticed in passing, that along the sides of Loch Broom the exposed surfaces of rock are usually well rounded, smoothed, and scratched, the striæ running parallel to the direction of the fiord, *i.e.* N.W. and S.E.

From Ullapool the road skirts the shore to the head of the loch, and abounds in natural as well as quarried sections of the strata. The quartzose flaggy schists which overlie the metamorphosed band and the limestone have a steady dip towards the south-east, of about 15° or 20°; sometimes, however, as about four miles south from Ullapool, they rise to 50° or 60°, but immediately subside again to their wonted gentle angle. At Fascrianach, about eleven miles from Ullapool (the first stage on the road to Dingwall), there is an admirable section both along the wayside and in a deep narrow gorge on the west side of the road. The strata here are micaceous quartzose flagstones, many of which seem hardly at all altered; indeed, we instinctively broke open the fissile plates, half hoping to find between them some fucoid or other impressions. The dip is on the whole south-easterly, at angles of not more than 3° or 5°; but the beds are here in slight undulations.

At the eleventh milestone the beds are in places irregularly laminated, and split with a tough, uneven, gneissose fracture. They are penetrated by irregular veins of white quartz, which run slightly oblique to the planes of bedding, though in a general sense parallel to them. But even these irregularly foliated bands are both underlain and covered by the usual fissile finely-laminated flagstones, where the layers of stratification are as parallel and unbroken as in any freestone-quarry among the Carboniferous rocks of the south.

At the branch-road to Dundonald the flaggy beds become darker and more gneissose, and begin to assume a contorted aspect. The dip, too, increases, and eventually becomes vertical. We crossed the great Dirry More to Contin; but over the greater part of this wild region the rocks are wholly obscured. It appeared to us, however, that the gneissose beds at the Dundonald road, after being crumpled and contorted in a synclinal axis, probably rise again with a north-westerly dip. It seems almost certain, at least, that between that locality and Ben Wyvis there must be many archings, like that on Loch Fannich before described*, so that the same group of rocks is repeated again and again; but even then the actual thickness of this upper quartzose and gneissose series must be admitted to be very great.

Returning to Ullapool, we shall now describe the course of the lower quartz-rock, limestone, and upper quartzose series towards the south.

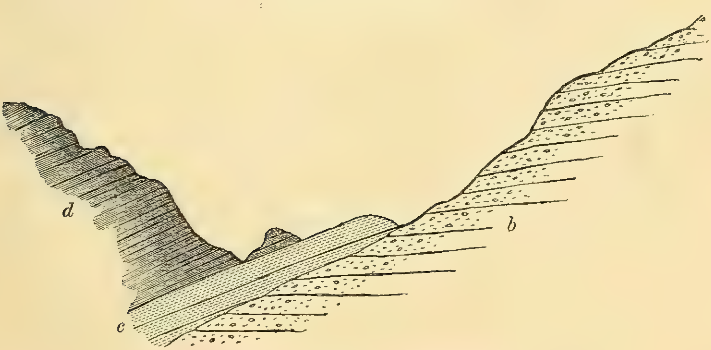
From Loch Broom to Loch Maree.—The region between Loch Broom and the head of Loch Maree is one of the wildest in the

* Quart. Journ. Geol. Soc. vol. xv. p. 387.

North-west of Scotland. There is no road, and for many miles not even so much as a mountain-track. Wastes of brown moor and shaking bog; glens once inhabited but now desolate; lonely tarns, the haunt of the wild duck and the curlew; and mountain-ranges that stretch away to the Western Ocean on the one side and the North Sea on the other, and sweep upward among the everlasting mists—such are the features of a region that seems never to have been trodden by foot of geologist. It abounds, nevertheless, with striking and instructive natural sections. In no part of the North-west Highlands can the order of superposition be more distinctly seen than in this wild mountain-tract between Loch Broom and Loch Maree.

Crossing Loch Broom at Ullapool, the same rocks are found in the same order, save that the limestone seems not to exist; nor does it come in again for a long way to the southward. Such disappearances of the calcareous parts of the series are of frequent occurrence throughout the whole of the Scottish Highlands, as in the Silurian formations of England and Wales. The quartz-rock and Cambrian sandstones sweep over the hilly ground of Ben-nam-Ban, and descend into the valley at the head of Little Loch Broom, near the Mansion of Dundonald. From this point they were traced by one of us southward, up the gorge of Corry Hourachan. Here there is a clear section, which is represented in the accompanying woodcut (fig. 6).

Fig. 6.—*Section at Corry Hourachan, South-west side of Little Loch Broom.*



b. Cambrian sandstone and conglomerate.
c. Quartz-rock. *d*. Gneissose schists.

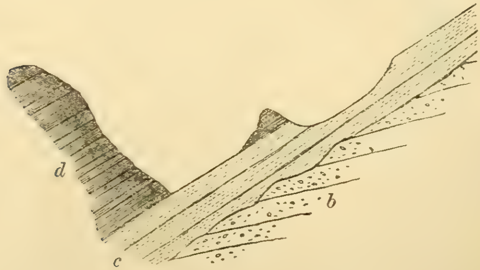
The stream has cut a deep channel, partly in the line of junction of the quartz-rock and schistose series, and partly transverse to it, the completest possible sections being thus exhibited. At its lower part the stream runs on quartz-rock; but higher up it is crossed by this rock, which then forms the western side of the ravine, the upper schists being peeled off and left as a cliff on the east side. A short way above this the schists too cross, and sweep up the western side of the valley. The quartz-rock ascends for a short way along the flanks of the mountain-mass of Kealloch—an enormous denuded range of gently inclined Cambrian sandstones.

From the head of the Corry Hourachan to the *bealloch* at the S.E. end of Strath-na-Shallag, there is a broken track that winds among a succession of knolls and crags, rising out of a bare moor. These show well the character of the passage-beds of the quartz-rock into the upper quartzose series. No igneous rock was observed in the whole district; and the metamorphic band of Loch Broom seems to have died away.

At the head of Strath-na-Shallag, a streamlet descending from the east has laid open a good section of quartzose grit, argillaceous shale, and gneissose bands, some of the strata showing annelide-burrows. It seemed a hopeful locality in which to look for fossils; but our time did not admit of a careful examination of the rocks. Limestone was formerly worked here; but the bed escaped our search.

Ascending the valley of Loch Ned, a section occurs similar to that of Corry Hourachan. The east side of the glen is capped by the upper gneissose beds; below these comes the quartz-rock, which in turn rests on the Cambrian sandstones that occupy the bottom of the valley, and rise up into the group of mountains lying between Loch-na-Shallag and Loch Maree. As we ascend the valley, the quartz-rock descends into the bed of the stream, and then begins to ascend on the western side, stealing up the hillside, the inclination of which nearly corresponds to the angle of dip of the beds. The gneissose beds have been swept out of the bottom of the valley, but they occur as outliers on the western side. Of this there is one striking example a little above Loch Ned. The eastern slopes of Scour Van slope down to that lonely tarn, and their lower parts are coated with quartz-rock. A stream here descends in a series of cascades, which, from the snowy tint of the quartz-rock and the sombre hue of the Cambrian sandstones that form the higher grounds, are rendered eminently picturesque. The watercourse for some way runs on inclined planes of quartz-rock, above which, in distinct superposition, are two dark peaks, outliers of a greenish serpentinous and actinolitic gneissose rock, with veins of red felspar (fig. 7). The

Fig. 7.—*Section at Loch Ned.*



b. Cambrian sandstone and conglomerate.
c. Quartz-rock. *d*. Gneissose schists.

scenery of the Loch Ned Valley affords another excellent illustration of how closely the physical aspect of a country is linked with its geological structure.

Beyond the head of Loch Ned the glen bifurcates,—the eastern part, or that to the left, leading to Loch Vrin, and thence to the Ullapool road at Fascrianach, while the western branch ascends by the Bealloch-na-Cros to Loch-na-Fad. The latter glen has been deeply cut by a mountain-torrent; and its sides are likewise scarred and grooved by watercourses, which, though usually dry, or nearly so, are rapidly filled by the rains which sweep down the declivities, leaving the bottom of the pass strewn with débris. Red felspar is here especially abundant, mingled with a dark chloritic gneissose rock.

Ascending to the summit of the Bealloch-na-Cros, over heaps of rubbish in which felspar fragments are especially numerous, we have a wide view of the surrounding mountainous ranges. The rocks on either side have a decided easterly dip on the sides of the glen and along the slopes of the adjacent hills, especially those which encircle the gloomy Corry Vichkerracher (Farquhar's Corry). The sheet of water called Loch-na-Fad lies before us. Beyond it, to the west, rise the enormous masses of Cambrian sandstone and Laurentian gneiss that form Sleugach and the neighbouring mountains which shoot up from the depths of Loch Maree.

A little on the west side of the upper part of the bealloch, a ravine exposes the white quartz-rock, dipping a little north of east, at 10–15°. From this point to Loch-na-Fad, the descent lies over mounds of débris of white quartz-rock and red felspar. Both these rocks protrude in detached hummocks and knolls. Near the lake, the felspathic rock becomes serpentinous, and we then, at the south end of the lake, come upon a limestone of considerable thickness, dipping to the north-east. We were informed that limestone was worked at the north end of the loch, at a place called Glen Tulloch, but not in so thick a bed as that of Loch-na-Fad. The latter we regard as a continuation of that seen in Glen Cruchalie, which will presently be described.

That this limestone occupies, on the whole, the same horizon as that of Ullapool, Drumdrynie, and Assynt, can hardly be doubted. The amount of drift by which it is surrounded, however, does not admit of a close examination of its junctions with the adjacent rocks; while the time at our disposal proved much too short for such a scrutiny as this portion of the line of outcrop deserved. It is quite possible that there may be some faulting here, and even to a considerable extent, though the general order of succession remains sufficiently clear. The metamorphism which is often most intense in the vicinity of a limestone is conspicuous here. The serpentine increases as we approach the calcareous beds; and, did the drift-covered surface permit, we might in all likelihood find the one rock passing insensibly into the other.

Below the limestone lies the usual white quartz-rock, creeping up the acclivity on the west side of the loch, with a gentle north-easterly dip. The lake empties itself by the River Hassac, which, flowing down a deep, precipitous gorge, enters the head of Loch Maree. Where the stream quits Loch-na-Fad, the Cambrian sandstone sets in, extending up the loch and down the river, and rising up into the great mountain-masses already referred to. The descent of the ravine of the Hassac, by a tortuous and usually imperceptible track, brings before the geologist a noble natural section. On the south, or left side, the Cambrian strata rise for some way up the cliff, capped by the white and grey beds of quartz-rock. On the other side the latter strata are absent, and the Cambrians form the craggy scarps of the ravine, till they are succeeded further down by the subjacent Laurentian gneiss.

Loch Maree.—Loch Maree, one of the wildest of Scottish lakes, presents a series of sections of singular clearness. With Kinloch Ewe as his head-quarters, the geologist has a wide sweep of interesting ground around him ; and we know of no locality where he may better acquaint himself with the order of superposition of the ancient crystalline rocks of the Highlands, or with the dislocations and metamorphism which they have undergone (fig. 8).

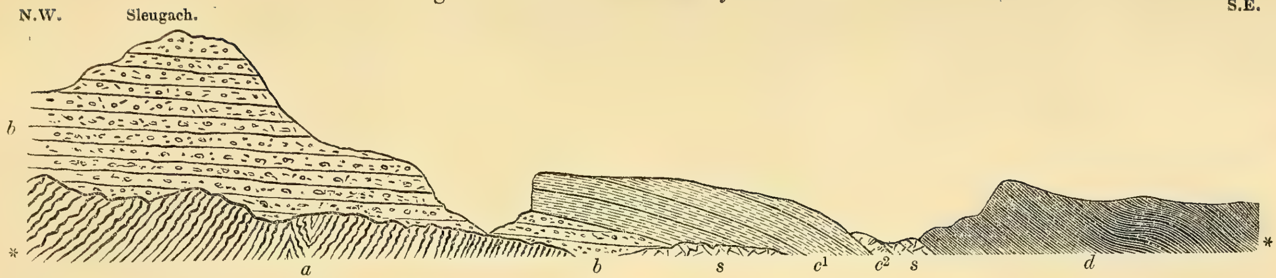
The occurrence of the Laurentian gneiss on the banks of this lake has been already described in this memoir, as well as the superjacent Cambrian sandstones, and the inferiority of these to the white quartz-rock. From the mouth of the Hassac river, up the valley, to the opening of Glen Cruchalie, the quartz-rock forms the north-eastern side of the valley; for the Cambrian strata rapidly dip below the surface. A felspathic rock, however, occupies the lower part of the cliff, and even rises to a considerable height above the valley. The same, or a similar mass, occupies, as we shall immediately see, a large part of Glen Cruchalie.

The quartz-rock dips in a south-easterly direction, at various angles, up to 35° or 40°. It is worthy of remark, that it extends further south-east on the northern side of Loch Maree than on the southern. On the former it continues to the line of Glen Cruchalie, where it is overlain by the limestone; on the latter it ends at or near the Inn of Kinloch Ewe, where, in the bed of the stream, are flaggy gneissose beds, indicating the upper series. The strata on the one side of the valley, if prolonged across, would abut against the edges of a different set of strata. Either, therefore, there must be a very sharp and sudden change in the strike of the rocks between Glen Cruchalie and Kinloch Ewe, or a fault must traverse the valley along the line of Loch Maree. The latter explanation is probably the true one. This fault, however, it is needless to remark, does not in the least degree obscure the order of succession.

The upper beds of the quartz-rock are well exposed in Glen Cruchalie. They dip south-easterly, at 35°, and show large surfaces covered with annelide-burrows. They are immediately succeeded by beds of bluish-grey and red mottled limestone, with shaly bands, having the same general inclination.

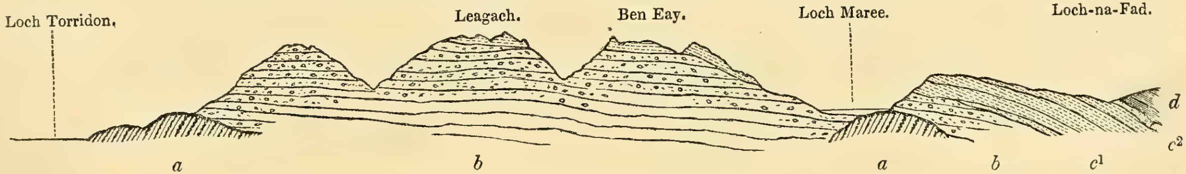
In Glen Cruchalie the most marked rock is one similar to that which was described as overlying the limestone at Loch-na-Fad, and underlying the quartz-rock at the mouth of the Hassac and

Fig. 8.—*Section at the Head of Loch Maree.*



a. Gneiss. *b.* Cambrian sandstone and conglomerate. *c^1.* Quartz-rock. *c^2.* Limestone.
d. Gneissose schists. *s, s.* Syenite. ** Level of Loch Maree.

Fig. 9.—*Section from Loch Torridon across Loch Maree to Loch-na-Fad.*



a. Gneiss. *b.* Cambrian sandstone and conglomerate. *c^1.* Quartz-rock.
c^2. Limestone. *d.* Gneissose schists.

along the higher part of the valley of Loch Maree. It is difficult to give this rock any one specific name; for, like that in Sutherland, which we formerly described*, it varies greatly in mineral composition, even within a few yards. Near the limestone it is a serpentine; the green mineral then thins away, and quartz and felspar take its place, while to these is occasionally added hornblende. The proportions of the ingredients also vary to a large extent.

This rock, by whatever name we designate it, occupies a large part of Glen Cruchalie. Sometimes it lies only along the bottom of the glen; then it rises high on the one side, and soon ascends among the slopes on the other. In some places it occupies indifferently the place of the limestone, in other parts that of the quartz-rock or the upper flaggy series, or it invades the three zones at once. But, though it forms an important feature in the geology of the district, and occupies a considerable area, it does not interfere with the ascending order, which is here, as everywhere to the north, quartz-rock, limestone, and upper flaggy or schistose beds.

The latter series of strata can be examined with advantage up the ravine, along which the road winds from Kinloch Ewe to Auchenasheen. It consists of quartzose and micaceous flagstones and schists, the south-easterly dip of which is well seen along the higher slopes of the glen, the angle varying from 25° to 50° These rocks clearly overlie the limestone, and are as dissimilar lithologically to the Laurentian gneiss (with which Professor Nicol would identify them) as two groups of strata can well be.

Loch Maree to Loch Torridon.—Few mountains in Scotland present a more striking aspect than those which close in around the head of Loch Maree, and stretch westwards to the Atlantic. Giant, sombre-hued masses of Cambrian sandstone, in nearly horizontal beds, rise, band over band, to a height of fully 3000 feet. Their summits are not unfrequently capped with white quartz-rock; and under certain phases of the sky, when a gleam of sunshine falls on these hill-tops, they seem in the distance as if tipped with snow. The illusion is sometimes heightened by the faults, which let down the quartz-rock in wedges among the dark-hued Cambrian beds; for then the white crags, descending some corry with a long stream of grey rubbish below them, look like a stunted glacier, or an incipient avalanche.

The general aspect of these hills is shown in the preceding diagrammatic section from the sea at Loch Torridon, across Loch Maree, to Loch-na-Fad (fig. 9). The same geological characters mark the high ranges from Leagach and Ben Eay to the Dingwall road at Craig Inn. Some of the features of this tract it is necessary to advert to more in detail. The rocks are faulted in a very extraordinary manner; and these dislocations have been supposed to lend some countenance to the hypothesis that the upper gneissose series, which rests on the limestone, is the Laurentian gneiss, brought up from the bowels of the earth by a convulsion of unknown magnitude. It would indeed be strange if, in a country so metamorphosed and mineralized, presenting so many crumplings and contortions of the

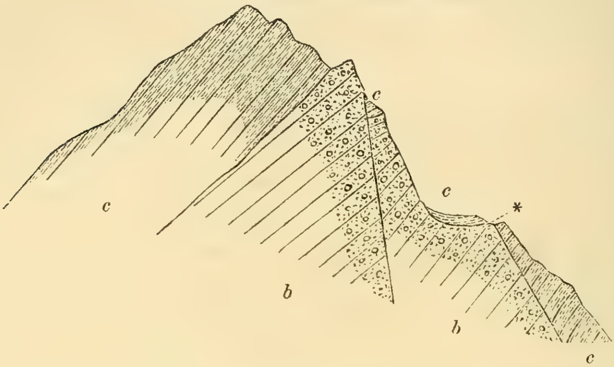
* Quart. Journ. Geol. Soc. vol. xvi. p. 238.

strata, and abounding in so many deep gorges and ravines, there were yet no lines of extensive faulting. Such lines must almost necessarily exist. But what are the conditions needful for their discovery? Must we not have at least certain persistent strata of well-defined lithological characters, and trace them in their windings among the mountains? Such strata, however, are not well represented among the Silurian rocks of these regions. The limestones, as we have seen, are subject, as in Wales and Siluria, to sudden and capricious changes, amounting even to entire disappearance. The upper gneissose series has no distinguishing band, and, where the limestone is wanting, passes down imperceptibly into the quartz-rock. The quartz-rock, too, has a more or less uniform aspect throughout; so that faults, repeating one part of it against another, might easily escape observation. If, however, we could find it on some exposed hillside, faulted along with its subjacent Cambrian sandstones, there would then be every probability of detecting the fractures; for the quartz-rock being white, and the Cambrian dark reddish-brown, any alternation of these two formations would be observable even at a distance. This desideratum is admirably supplied among the craggy mountains of Beann Taobhliath, which, from within four or five miles of Loch Maree, extend southwards almost to Loch Doule, on the road between Dingwall and Skye. The hillsides along the deep glens in that region afford the clearest and most startling proofs of dislocation; and yet, but for the contrasting colours of the two series of rocks, these fractures would probably never have been detected, unless, with a good map in his hand, a geologist had set out purposely to seek for them. Hence it is in the highest degree probable, that among the gneissose rocks there may exist many large faults, which have not been even suspected.

Having made this admission, however, it by no means follows that over the region we have examined any kind of fault may occur, and along any part of the line. In the sections already described in this paper there is certainly no fault, but a clear order of superposition from the lower quartz-rock into the upper quartzose or gneissose series. But between the points which we have selected for description in detail, it is far from improbable that faults may intervene, limited in their extent and in their amount of throw. They can only be local; and their character is probably sufficiently shown in the region, one or two sections in which we shall now describe.

Beann Taobhliath, or "the Grey Heads."—About 5 or 6 miles south-west from Kinloch Ewe, on the road to Loch Torridon, lies the watershed between that arm of the sea and the freshwater Loch Maree. On the north side of the valley the mountains of Leagach and Ben Eay, already referred to (fig. 9), show their capping of white quartz-rock on the sombre-hued Cambrian sandstones which form their mass. It was the southern side of the valley, however, that chiefly attracted our attention. There the quartz-rock on the mountains, when seen from the road, appeared interbanded with some dark rock, as if sheets of greenstone had been thrust between its strata. This seemed the more inexplicable as we had seen no such rock in any other part of the district, and none certainly which showed such a regularly stratified arrangement. One of us, accordingly, ascended the craggy sides of Scuir Dhu, and thence obliquely southwards to the top of the highest of the Beann Taobhliath hills, or "Grey Heads." The following section represents, better than any detailed description, the structure of Scuir Dhu.

Fig. 10.—*Section of Scuir Dhu.*

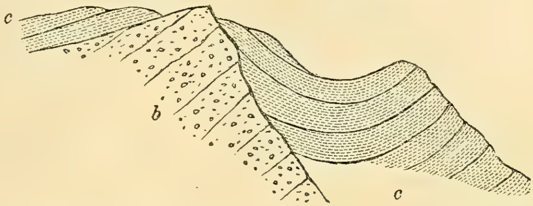


b. Cambrian sandstone and conglomerate. *c*. Quartz-rock.

The Cambrian at the base of the hill dips E. 10° to 20° S., at 30° to 40°. It is covered by white quartzite having the same dip and angle, and showing still the oblique lamination or "false-bedding" of the original sand. Did no other section exist, we should say that the Silurian rocks here followed the Cambrian in conformable sequence. The Cambrian beds slope up the valley along the lower part of the acclivity, while the quartz-rock rises above them to form the greater part of the north-eastern side of the glen. The latter rock is occasionally deeply channeled by mountain-torrents. One ravine in particular occurred in the course of the ascent, about 80 or 100 feet, and, in places, so narrow that it seemed as though one could almost have stepped across it. Cambrian blocks strew the hillside, and are often perched on the edges of cliffs and on the summits of detached crags. None of them are of great size, the largest observed being eight feet long, six broad, and three high. Gneiss-boulders also occur, but are small in size as well as few in number. The quantity of Cambrian blocks increases as we ascend, until, not far below the summit, we come upon a mass of Cambrian sandstone in place, dipping E. 4° S., at 27°. Between the quartz-rock and this Cambrian ledge there is undoubtedly a fault, the former rock having its beds curved and thrown back against the latter: this is shown in the subjoined section (fig. 11), which is an enlarged view of that part of fig. 10, marked *. The Cambrian beds are then covered over by flat undulating beds of quartz-rock, which lie at the base of a cliff of similar Cambrian sandstones. At the top of this cliff a small ledge of quartz-rock exists (as shown in fig. 10), let in by a fault below another Cambrian crag, above which comes a snowy cliff of quartz-rock, forming the summit of the mountain.

The Cambrian rocks support hardly any vegetation, the quartz-

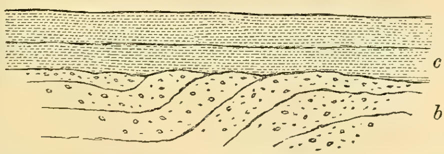
Fig. 11.—*Enlarged Section of the Point marked * in Fig.* 10.



b. Cambrian sandstone and conglomerate. *c.* Quartz-rock.

rock still less. There is, therefore, no obscuration of the lines of junction, save such as arises from the débris of the crags, worn down as these are by the rains and frosts of winter, that tell especially upon the quartz, splitting up its beds and covering its surface with piles of loose, rough, angular blocks, on which it is often perilous to tread. There is no difficulty in determining which are lines of fracture and which lines of regular superposition: the section, indeed, is nearly as distinct as it can be drawn on paper. The uppermost ledge of red sandstone dips E. 4° to 10° S., at 30° to 36°; the quartz-rock which covers it dips E. 4° to 10° S., at 35° to 42°. These figures are given as the mean of several observations made at intervals along the exposed ledges. They show that, in a general sense, the two series of deposits are conformable; and this conformity, could we obtain unweathered surfaces for careful measurements, might be shown to be complete. It is sufficiently evident, however, that this undisturbed sequence is accidental, and that the Cambrian beds had undergone erosion previous to the deposition of the overlying deposits. In no instance is there anything like a passage of the one series into the other; on the contrary, everywhere along the junction the line of demarcation is sharp and defined. Such sections as that given in the annexed figure (fig. 12), are not uncommon where a

Fig. 12.—*Section showing the Junction of the Quartz-rock and the Cambrian Sandstone on Scuir Dhu.*

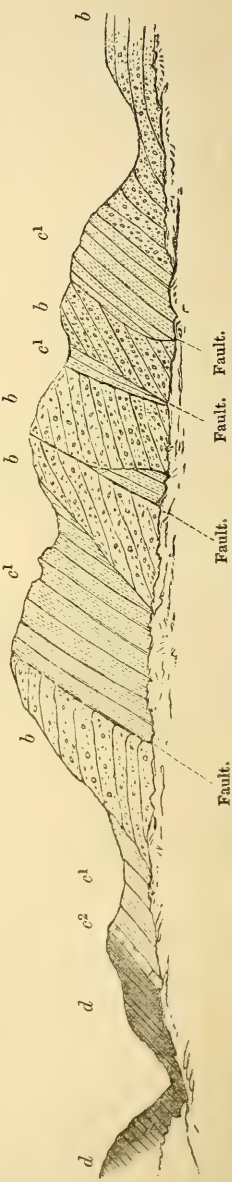


b. Cambrian sandstone and conglomerate. *c.* Quartz-rock.

bed of red sandstone has been at one point eroded, and is there unconformably overlapped by the quartz-rock.

From the summit of the hill the quartz-rock plunges down the north-eastern side towards the valley of Loch Clare; but the Cambrian again comes in, owing to the intervention of other faults. Crossing along the ridge to the next hill to the south, we meet with other examples of the apparent interbedding of quartz-rock and red sandstone. There is a gorge or *bealloch* (of which we could not ascertain the name, and it is nameless on the maps) on this ridge, having a stream on the east side, which descends into Loch Coulan, and another on the west, that falls into the valley of the Torridon Water. Following the line of the glen on the south-east side, we are presented with one of the most striking natural sections anywhere to be seen in the North-western Highlands. The alternations of red sandstone and white quartz-rock are repeated again; but here, in place of merely an outcrop-line along the strike, we have a magnificent transverse section several hundred feet deep, along the southern side of a wild glen. The contrasting tints of the two rocks give the declivity all the appearance of a vast diagram; and no diagram could represent the dislocations in a more impressive manner. The subjoined figure (fig. 13) was copied while we walked down the glen, and represents, as nearly as may be, the actual relations of the rocks. We may add, that the same dislocations cross to the north side; but the greater amount of débris on that side makes them less easily traceable. They undoubtedly run both north and south of the glen; and these mountains have thus the singular aspect of alternating cliffs of snowy whiteness and sombre brown. We could mark the arrangement on the hills a short way north of the Dingwall road at Loch Doule, a distance of fully ten miles from Ben Eay, where similar dislocations were

Fig. 13.—*Sectional View of the Dun Tolleah Hills.* Length 2 miles.



b. Cambrian sandstone and conglomerate. *c*1. Quartz-rock. *c*2. Limestone. *d.* Gneissose schist.

also observed. The map of this region would therefore represent a series of irregular strips and patches of Silurian quartz-rock, inserted among Cambrian sandstones by the agency of longitudinal faults which seem to split off from or coalesce with each other.

Towards the lower end of the valley the quartz-rock dips E. 10° S., at 35°, and is followed by a band of limestone conspicuous from the neighbouring hill-tops, owing to the bright verdure that marks its course. Above the limestone come beds of quartz-rock and quartzose flagstone; and these, becoming more and more schistose, cross Loch Coulan, and are seen in the ravines and watercourses on the opposite side. They form, of course, the upper quartzose series so frequently referred to.

The region lying between the Grey Heads and Loch Doule has never been explored. We were able to see its general structure from some of the neighbouring hill-tops; but it must contain much interesting detail to reward the fatigues of an enterprising geologist.

Loch Carron.—After traversing this faulted district, the quartz-rock approaches Loch Doule, whence it bends towards the south-west, occupying the high ground on the north-west bank of Loch Carron. At the head of the latter loch it is overlain by a limestone, which extends for some way towards Jeantown, until lost beneath the alluvial accumulations of the valley.

The road from Jeantown to Applecross crosses a high ridge, and descends to Loch Keeshorn, through a ravine in which there is a well-exposed section of the strata. First, on leaving Jeantown, we have schistose beds with a south-easterly dip; these gradually pass down into a quartzose and flaggy series, which towards the lower end of the ravine are underlain by the quartzite. The next rock in descending order is a limestone of great thickness, which occupies the south-eastern side of Loch Keeshorn*. It dies rapidly away to north, and a short way beyond the head of the loch has disappeared altogether. It is underlain by white quartz-rock, which, coalescing with that above the limestone, forms one series, below which lie the Cambrian sandstones swelling up into the great mountains of Applecross and Loch Duich.

We had not time fully to work out the relations of the Keeshorn limestone: possibly it may be the same as that of Loch Carron, Loch Coulan, and Glen Cruchalie—that is, the limestone zone between the lower quartz-rock and the upper quartzose flaggy series; or, like the lower limestone of Ben Eay, already referred to, it may be a local deposit occurring in the lower quartz-rock. The area which will decide this point is the high ridge on the northern side of the Loch Carron Valley, between Lochs Keeshorn and Doule.

The sections along the shores of Loch Carron at Strome Ferry are singularly clear. They show the quartzose flagstones in well-defined beds, dipping sharply to the south-east at 45° or more. The same rocks occupy the intervening tract of land to the Kyles at Balmacarra, where another admirable line of section can be examined along the shore.

* See Nicol, Quart. Journ. G. S. vol. xiii. p. 29: Murchison, *ib.* vol. xv. p. 188.

Loch-alsh.—The promontory opposite Kyleakin has hitherto been mapped as "Red Sandstone," like the hills of Applecross, that is, "Cambrian" according to our classification of these rocks. Next to this red sandstone, there has been inserted on the east side a strip of quartz-rock, beyond which, at Balmacarra, comes the great "gneiss" region of previous geologists*. The red sandstone, however, is not identical with that of Applecross, or the red sandstone of the west coast generally; indeed, so far as we observed, it is rarely red sandstone at all, but greyish quartz-rock, which assumes a pink or reddish tint, chiefly on the weathered surfaces. It has an E.S.E. dip at gentle angles. Opposite Kyleakin, indeed, there is a confusion of the bedding, owing perhaps to the prolongation of a fault from Skye, to be immediately noticed; but east from this the stratification becomes quite regular. The quartzy flagstones, in well-defined beds, dip steadily up Loch-alsh, at from 15° to 20°; towards Balmacarra House, interlaminations of shale or schist begin to appear; and these continue to increase, imparting a fissile character to the strata. As we trace the strata still eastward, their schistose structure increases, until, by the diminution of the quartzose bands, and the greater development of the argillaceous and micaceous portions, they insensibly pass upwards into schists and gneissose rocks; these range eastwards up Loch-alsh, with here and there a boss of syenite, or felspar-porphyry. No clearer evidence could be desired, that the quartz-rock or quartzose flagstones graduate in perfect lithological sequence into the upper schists.

In Sutherland, as stated in former memoirs, the quartz-rock above the Assynt limestone is superposed by another limestone, which, however, is of no great continuity. We failed to detect it in any of the transverse sections of the country between Assynt and Loch-alsh. Along the shores of Loch Duich, however (which is a branch of Loch-alsh), the schists that overlie the upper quartzose flagstones contain, in their lower part, several limestone bands, in the same way as the Sutherland limestone lies between the upper quartz-rock and the superjacent gneissose rocks.

Loch Duich.—The Loch Duich limestones are best seen along the south side of the fiord. There are at least five or six bands having a general easterly or south-easterly dip. They are separated by talcose, actinolitic, and micaceous schists, often serpentinous like the limestones themselves: red felspar-porphyry and syenite also occur in bosses, dykes, and veins. The longest beds of limestone are perhaps those of Totig Point, opposite the village of Dornie and Eilan-Dounan; there they are sometimes pure white, with green serpentine streaks, and have been quarried on the shore†. They range across the hills into Glenelg.

Red felspathic rocks abound chiefly towards the head of Loch Duich; they are conspicuous in the hill of Mam Rattachan, and likewise in many of the gullies and clefts worn on the hillsides by the rains, as well as on the shore. We found them also among the

* See especially Prof. Nicol's map, where these errors are to be seen.

† See Quart. Journ. Geol. Soc. vol. xiii. p. 30.

flaggy beds of the Bealloch of Kintail, which, with a south-easterly dip, range northwards to the deep gorge of the Glomach, where, in a scene of singular wildness and grandeur, the stream, in falling over the cliffs, gives rise to the highest cascade in Scotland.

Skye.—Following the line of outcrop of the Lower Silurian quartz-rock and limestone, we have arrived at the shores of the Atlantic. But these rocks are prolonged into the Island of Skye; and before tracing the structure of the interior of the mainland, we will sketch in outline that of Sleat—the southern peninsula of Skye.

In a former memoir*, it was shown that the Lias of Strath, in Skye, rested unconformably upon red (Cambrian) sandstone, and that the sandstone stretched across the island from sea to sea, with a north-westerly dip. It was also pointed out, that some powerful faults existed in the district, whereby the secondary shales and limestones were thrown down in wedge-form among the older strata. We have now ascertained that the same faulted character extends across Loch Eishort into Sleat, rendering the geology of that peninsula intricate and difficult. With the limited time at our disposal, and the want of a map having any approach to accuracy, we did not attempt to work out the detailed structure of this region.

Sleat appears to have formed originally, previous to the occurrence of the faults, an anticlinal ridge consisting fundamentally of Cambrian sandstone with the quartz-rock, limestone, and upper gneissose beds folded over it. Traces of this simple structure are sufficiently abundant; but it has been greatly modified and deranged by the influence of certain longitudinal dislocations, by which the north-western side of the arch has fallen in; and considerable confusion has been introduced into the southern end of the peninsula.

The Cambrian, rising from under the Lias, forms the north side of Loch Eishort and runs across to the Bay of Lussay. From the head of Loch Eishort a fault extends to the shore near Kyleakin, the effect of which is to throw down the quartzose flaggy beds against the Cambrian sandstones, both of which have a north-westerly dip. Another fault runs probably from about Kyleakin, along the north-west flank of Ben Cailleaich, towards the Point of Sleat, with the same effect as the other; so that the arch becomes still further fractured towards the south-west end of the island.

At Ord the red sandstones are also considerably faulted. On the hills above the House they are surmounted by quartz-rock in thick beds of snowy whiteness. These dip north-west, at a steep angle, forming the side of a steep hill, at the bottom of which they are covered by limestone, evidently on the same horizon with that of Assynt and Loch Broom.

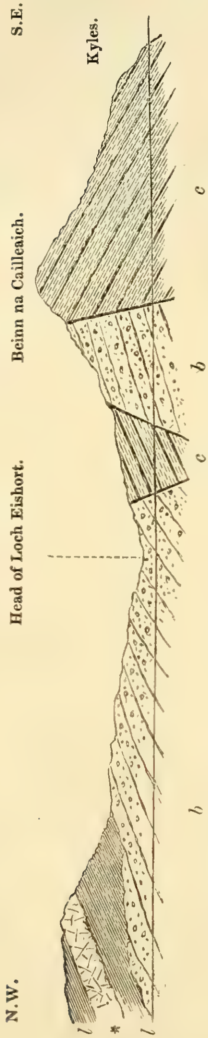
This limestone appears to be surmounted by quartz-rock; but this part of the island is dislocated to no common extent, and would require much care and time in the unravelling of its details †.

* Geikie, Quart. Journ. Geol. Soc. vol. xiv. p. 1 *et seq.*

† I am now convinced that the white quartz-rock noticed in my former paper as wedged in at the side of a fault on the shore of Loch Eishort really belongs to this Lower Silurian series, and is therefore the product of a much older meta-

Returning to the shore opposite Balmacarra we find that the quartzose flagstones already described cross into Skye and form the great mountain-mass of Ben-na-Cailleaich. Their dip on the north-

Fig. 14.—*Section through Sleat in Skye.*



b. Cambrian sandstone and conglomerate. *l.* Lias Shales, with syenite and greenstone (*).
c. Quartz-rock.

Fig. 15.—*Section across Sleat in Skye.*

b. Cambrian sandstone and conglomerate. c^2. Limestone.
c^1. Quartz-rock. *d.* Gneissose schist.

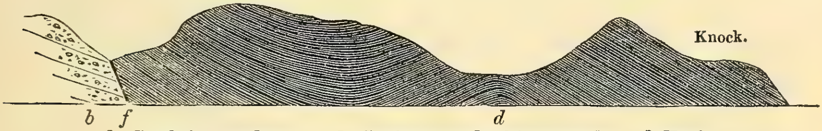
western side of the anticlinal arch is obscured by the faults; but their south-eastern dip is well shown along the bare grey slopes of the

morphism than that of the Lias limestones. It occurred to me also, last summer, while on the hills above Ord, that possibly some parts of the metamorphic limestone of Strath may possibly be also Silurian.—A. G.

hills. The same dip continues by Kyle Rhea along the south-eastern shore of the island, which is traversed by numerous N.W. and S.E. dykes of greenstone. The same reddish tint is here observable that was noticed in the description of the Balmacarra flagstones. The cause is the same in this case also; the red colour is a mere crust owing to the oxidation of some of the component minerals; while the rock, when broken, is grey or white within.

At Isle Oronsay, as at Balmacarra, we found a gradation from these flagstones into the upper gneissose or schistose series. These schists have a south-easterly dip, but are much crumpled in places. Near

N.W. Fig. 16.—*Section in Sleat, from near Ord to Knock.* S.E.



b. Cambrian sandstone. *d.* Gneissose and schistose rocks. *f.* Fault.

Knock a good section is obtained from the shore inland, showing the curving of these strata, and about halfway between Knock and Ord they are seen to graduate as usual into a lower series of quartzose flaggy beds.

2. *Structure of the country between the Atlantic and the line of the Great Glen.*—Having traced the southward prolongation of the quartz-rocks and limestones in Skye, until they are lost beneath the waters of the Atlantic, we now give the results of several traverses of the region to the east of these rocks, in order to show the character of the upper gneissose series of deposits and the geological structure of this part of Scotland. In former memoirs upon the rocks of Sutherland, reference was made to the great apparent thickness of the flaggy schistose strata which there overlie the upper limestone and form the central and eastern portions of that county. The thickness was indeed so great as to compel the belief that many folds must necessarily exist, even although in most of the observable sections the rocks continued to plunge towards the south-east. But the data were wanting on which to speculate as to the character and amount of such folds. This summer, however, we were fortunate enough to obtain some illustrative sections which showed how deceptive this steady south-easterly dip might really be, and how probable it was that, even where no change in the direction of inclination could be traced, the strata might nevertheless be repeated upon themselves again and again.

Loch Broom to Contin.—One of us continued the section from Loch Broom across the wild uplands of the Dirry More to the Old Red Sandstone of the east coast, where it ascends the River Conon to Contin. The amount of alluvium along the valleys rendered the greater part of this traverse unsatisfactory; but enough was observed to justify the belief that when this region is properly mapped it will be found to contain many anticlinal and synclinal folds as well as local contortions of the strata. The flaggy and gneissose beds from Inisbae to Contin have, on the whole, a south-easterly dip. On the shores of Loch Garve the gneiss is crumpled into intricate folds; but the prevalent dip is still south-easterly, and continues so until the Old Red conglomerates supervene at Contin. Alternations of micaceous gneiss, mica-schist, and grey quartz-rock form the prevailing rocks of the district. From Contin we recrossed the country to Loch Carron. The same gneissose schists and quartzose flagstones were observed along the road, with a general south-easterly dip, but with several visible folds and many covered parts where a north-westerly dip may occur, like that of the mountain Aigean on Loch Fannich, before described*.

Loch Hourn by Loch Quoich to the Caledonian Canal.—We examined also a line of section from about the middle of Loch Hourn to Loch Oich in the Great Glen. The rocks which form the magnificent jagged mountains that overshadow Loch Hourn are dark micaceous flagstones. They have a general south-easterly dip at high angles and are usually flat-bedded and regular, though sometimes locally crumpled. They occur all up the wild gorge or pass that rises from the head of the loch to the height of 1000 feet in the space of a mile. The top of this pass forms part of the main ridge of the country, and presents the singular phenomenon of a watershed only a mile distant from the sea on the one side, and fully fifty miles on the other. All the crags and rocks along the sides of the pass have been smoothed and striated, by glacial action, on the faces that look up the glen, while those which point down to the sea are rough and irregular. There is no drift in the glen nor at the head of Loch Hourn.

From the top of the pass to the bend of Loch Quoich the same rocks continue in the same south-easterly inclination. Near Mr. Ellice's house at Glen Quoich †, however, a line of synclinal axis crosses the lake and runs northward to Glen Shiel, where we found it well marked. On the east, or rather east-south-east of this line (for its direction is nearly north-north-east), the strata are reversed to the north-west, and this dip continues along Loch Quoich and for several miles to the eastward. They then undulate and become obscured partly by granite masses and partly by the deep sandy accumulations of Glengarry, so that their relations towards the Great Glen were not satisfactorily ascertained. At Invergarry Inn, however, only about two miles from Loch Oich, the gneissose rocks had a decided north-westerly dip.

The most instructive sections along this line of country were those in Loch Hourn, and on the road between that deep fiord and Tomdoun Inn. We would especially instance two rocks or cuttings on the wayside; one about three miles west from the house of Glen Quoich, the other at the seventh milestone west from Tomdoun Inn. The first of these shows in the clearest possible manner how deceptive

* Quart. Journ. Geol. Soc. vol. xv. p. 387.

† Since our visit to Glen Quoich, our hospitable host, the Rt. Hon. Edward Ellice, has acquired all the lands of Glengarry, so that his estates now range from Loch Oich to Loch Hourn, a distance of about 30 miles.

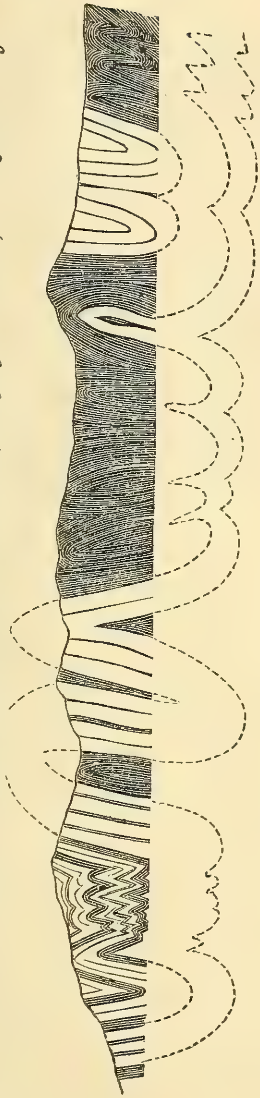


Fig. 17.—*Section showing Contorted Schists and Quartzose Beds (belonging to Series d) near Quoich Lodge.*

a prevalent dip in this region may be, even though it should seem to be perfectly regular. The strata, consisting of gneiss, mica-schist, and micaceous quartz-rock, are exposed for about 100 yards, and, as shown in the accompanying diagram (fig. 17), are folded upon each other in such a way that the same stratum is repeated seven times in that space. The actual thickness of the beds in this section is perhaps not more than 10 or 15 yards—that is, from a seventh to a tenth of their apparent thickness. In walking over the edges of these highly inclined strata, with possibly here and there the indication of a south-easterly dip, we might very naturally set down the beds as one continuous series; and, without a clear transverse section, it would be difficult to prove that they were not.

The other section is represented in fig. 18. It shows another way in which the vertical thickness of these upper gneissose rocks may be reduced from its enormous apparent magnitude. Instead of vertical folds, we are often presented, as in the rocks depicted in this figure, with contorted bedding, which even more than the former tends to modify our estimate of thickness.

There can be no doubt that these sections are truly typical of the structure of the metamorphic regions of Scotland. They show us how the rocks are folded on the small scale, while the synclinal axis of Loch Quoich proves how these are repeated by great troughs and arches. The large amount of repetition thus induced makes it no longer difficult to conceive that the gneissose and micaceous flaggy rocks of the Highlands do not attain so gigantic a thickness as they formerly seemed to do, and that in truth they need not be regarded as more than equal to the lower half of the Silurian system in other regions.

Arisaig to Banavie.—A transverse section which we examined with great care, and which perhaps offers the best natural exposures of the rocks, is that from the wild headlands of Arisaig to the entrance to the Great Glen at Banavie. At Arisaig we found the quartzose flagstones with a W.N.W. dip, traversed by innumerable greenstone dykes having a north-westerly direction. The same direction of dip continues along the road a mile and a half to the east of the village of Arisaig *. The strata are then reversed to the

Fig. 18.—*Section of Rocks on the Roadside at the 7th Milestone west from Tomdoun Inn.*

S.E. for about half a mile, after which they undulate in both directions, as is well shown along the crags near Borrodale, on Loch na Nuagh. Dykes of greenstone with a N.W. strike still abound. At the head of Loch na Nuagh the strata of micaceous quartzose schist have a S.E. dip at high angles. This inclination continues to near Loch Aylort, where the beds are vertical, sometimes leaning to the one side, sometimes to the other. Where the road descends upon that arm of the sea, the dip is south-easterly; but it is immediately reversed to the north-west. From the point whence the road diverges from the loch, the vertical and contorted strata are seen to be convoluted in rapid arches; after which, on again reaching the sea-margin, the dip is south-easterly.

At Kinloch Aylort, highly micaceous quartzose rocks, in well-marked vertical beds, strike N. 10° E., which exactly resemble those of Loch Hourn, showing the same alternation of grey quartzose bands with others strongly micaceous, but without the admixture of felspar. They are in places true mica-schists, in others quartz-rocks. The glaciated surfaces are here very apparent,—the vertical strata being smoothed and deeply grooved across their truncated edges; the direction of the groovings runs W. 30°–40° S.

About a mile and a quarter from Kinloch Aylort the schists are overlain by a band of quartzose flagstone, well bedded, and in some beds micaceous and fissile. The dip is exposed in a quarry by the roadside, being E. 30° S. at 77°.

From this point onward to the head of Loch Ailt, another series of micaceous quartzose schists occurs. The inclination is at high angles, often vertical. The strata are sometimes beautifully con-

* This is the Clanrannald country, now possessed by Mr. Dukinfield Astley.

torted, as at Ault Namuie, where they are curved and convoluted as at Loch Quoich, though the prevailing dip is still south-easterly.

At the watershed we begin to meet with a reversed or N.W. dip. The same micaceous strata are again traversed, with here and there a knob of quartzose granite. About a mile east of the watershed, contorted rocks are exposed in the bed of a stream which is crossed by the road.

At the foot of Glen Finnan, near the spot where Prince Charles first unfurled his flag, the dip changes to N., and then immediately to N.W. As we proceed eastward the strike becomes nearly N. and S., and the strata gradually assume a more gnarled, twisted appearance, granite being visible here and there. Such highly metamorphosed rocks continue to near the head of Loch Eil, where the micaceous series is replaced by hard grey quartz-rock, first in highly twisted and even vertical beds, with granite-veins. The dip then turns to E. 18° S. at 25°, exactly like the undulating quartz-rock of Glengarry; after which the dip is reversed to W. 30° N. at 20°–25°.

About one mile east from the head of the loch we observed fragments of red felspar in the streams. Two miles further on, the dip was S.E. at 20°–25°. At the distance of another mile the south-easterly dip still continued, but at a very gentle angle.

One mile and a half east of Fassafern the hard grey quartzose beds dip W. 25° N. at 17°–20°. Thence they undulate for four miles along the margin of the loch. We next found them in well-marked strata separated by layers of micaceous schist in a quarry by the roadside, where they dipped nearly due W. at 25°–90°. They are traversed by innumerable veins of a pink felspathic rock; and larger masses of a dark hornblendic rock are occasionally seen. Further on the dip still continues westerly, and, at Avat, is at an angle of from 25° to 30°. Four miles from Fort William another quarry occurs close to the road, where hard grey quartz-rock, highly micaceous in certain layers, and even passing into true mica-schist, dips W. 16° N. at 30°–40°. The rock is traversed by veins of quartz containing mica.

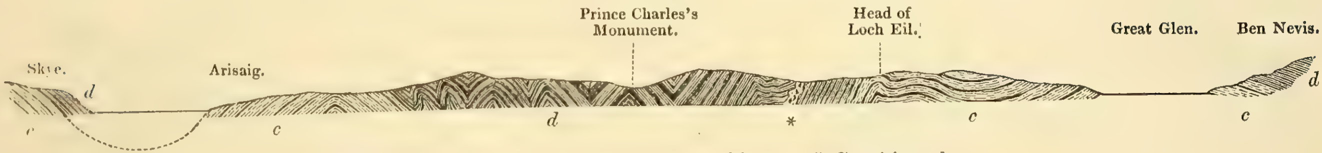
Near the church of Kilmallie the angle becomes much higher, the N.W. dip still continuing. Beyond this we reach an area of intense metamorphism, where porphyry and granite are intermingled with the schists and quartz-rocks in great abundance along the valley of the Caledonian Canal. This valley, moreover, is obscured by enormous accumulations of sand and gravel.

The annexed diagram shows the arrangement of the strata along the line just described. It will be seen that, viewing the country on the large scale, we are here presented with a wide synclinal trough of the schistose series, from beneath which, along either side, the underlying quartzose rocks come to the surface.

3. *Repetition of the Lower Silurian Quartz-rocks and Limestones East of the Line of the Great Glen.*

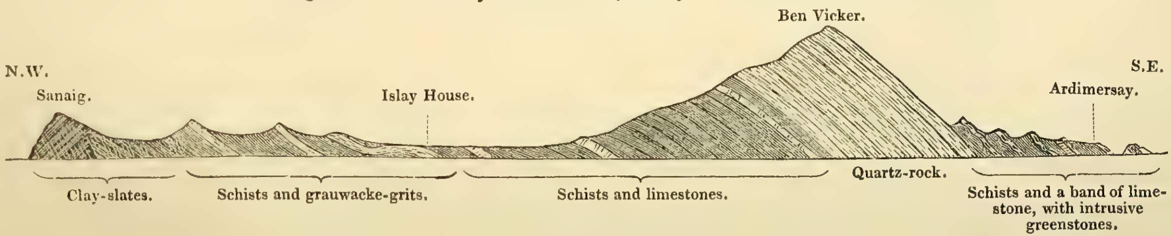
Line of Great Glen or Caledonian Canal.—We have shown that the quartz-rocks and limestones of Sutherland range south-westwards

Fig. 19.—*Diagram-section from Skye to the South End of the Great Glen.*



. Quartz-rock. *d*, Micaceous and gneissose schists. * Granitic rock.

Fig. 20.—*Section of the Island of Islay.* Length 20 miles.



through Ross-shire into the Isle of Skye,—that they are covered by a vast series of micaceous flaggy or gneissose schists,—that these are disposed as a great synclinal trough, the centre of which traverses the head of Glen Shiel, the middle of Loch Quoich, and the watershed at Glen Finnan,—and that, by the curving of this trough, the quartzose beds which form its outer or lower edge along the western coast at Arisaig are brought up again along the line of the Great Glen.

We shall now endeavour to describe the anticlinal arch of the Great Glen, and to point out how the same strata undulate to the eastward of that arch to form the remainder, or southern portion, of the Scottish Highlands.

The remarkable chain of lakes which extends from Inverness to Fort William presents, even on the roughest map, unmistakeable evidence of a line of fracture in the earth's crust. Loch Ness, deeper by many fathoms than the German Ocean, showed, in the sympathetic movement of its waters during the Lisbon earthquake, the depth and extent of the fissure which it occupies. So marked a line might justly be supposed to indicate a great displacement of the rocks. And yet, though the fracture is probably more extensive than any other in the country, it has not been attended, so far at least as we have yet been able to ascertain, with any marked upheaval or depression of the rocks on either side. We at present regard it as a fracture without a throw, or, at least, with such a throw as not at all to interfere with the regularity and perspicuity of the section.

The line of this chain of lakes, or the Great Glen, as it is properly called, runs along the line of an anticlinal axis. West of the lakes the strata (as we have seen along the banks of Loch Eil) have a north-westerly dip; east of this line they incline to the south-east. Moreover, it would seem that this axis lessens in intensity towards the north and increases towards the south; in other words, the southern prolongation of the arch brings up lower and lower beds, while in its northern extension it appears to be dying away. As we trace it southward from the grey quartzose beds last described at Loch Eil, we gradually re-encounter the whole of the Sutherland and Ross-shire succession of quartz-rocks and limestones, and obtain thus additional aid in correlating the crystalline rocks of the North-western Highlands with those of the central counties.

Islay and Jura.—By much the clearest and most complete series of these repeated strata occurs in the Islands of Islay and Jura, whence they range north-eastward up the Linnhe Loch, and south-westward into Ireland. The annexed figure represents the structure of Islay (fig. 20).

The rocks which form the N.W. promontory of the island at Sanaig were examined by us under the disadvantage of a storm of wind and rain. We ascertained, however, that they consist of clay-slate, which we believed to dip below the mica-schists and grit-bands of Sanaig-farm. They are well exposed on the shore, first with a south-east dip, which soon turns to the north-west, with which inclination they appear to plunge below the waters of the

Atlantic. The slate is cleaved obliquely to the bedding, the planes having, where we saw them, a marked S.E. slope. This rock weathers in a remarkable way along the precipitous headland of Sanaig. Seen through the mist, the hills seemed split open by deep narrow fissures, corresponding probably to joint-planes, while their steep faces had that peculiar jagged aspect which so often results from the weathering of cleavage and stratification combined.

If we are correct in assigning to these slates a position inferior to the grits and schists which in Islay represent the lower quartz-rock of Sutherland, it follows that they help to fill up a gap in the Silurian series which is wanting in the North. The Sutherland rocks unquestionably belong to the lower part of the Llandeilo series, and the Sanaig slates would accordingly represent the position of the Lingula-flags.

The slates are followed towards the east by what we at present regard as a superior series of schists and intercalated bands of quartzose grit. From this point there is no doubt about the order of succession. The strata dip towards the south-east,—the schists occupying, as a rule, the valleys and low grounds, while the bands of hard grit range along the island in more or less prominent ridges, or even rising up into no inconsiderable hills. The schists do not differ from those which have been already described; they are micaceous, chloritic, argillaceous, or quartzose in turn, and often much contorted in their lamination. The grit or quartz-rock is a hard grey siliceous rock, to which the old term "grauwacke" might well be applied. These strata occupy the whole of the western division of Islay, known as "the Rhinns,"—the schistose series being sometimes quarried for slates, as at Kilchieran, and the grits as rough building-stones. Granitoid rocks and true syenites are of common occurrence, and may be advantageously examined along the south-east side of the promontory at Port Charlotte. There, on the shores of Loch-in-Daal, the quartzose grauwacke and grey schist, dipping S.E. at 40°, are traversed by a red syenite, and are themselves highly metamorphosed, passing into quartz-rock and lydian-stone, in which a crystal of felspar may be occasionally detected. The decomposition of the syenite here has produced that chaotic assemblage of loose blocks (*felsen-meer*) so common in granitic countries. Dykes of greenstone with a general north-west range, but often irregular and tortuous, also occur among the strata of this coast-line as well as throughout the entire island.

As we trace these schists and grits towards the N.E. promontory of Islay, the former are seen to become considerably thinner, and the series then assumes much more of a quartzose aspect. This was particularly noticed on the high grounds to the north of Islay House.

The section (fig. 20) shows that above the grits there is a series of schists with three intercalated limestones. This upper series we refer to the horizon of the Assynt limestone. It lies upon a quartzo-schistose band, representing, as we have said, the lower quartz-rock of Sutherland. It is surmounted by a great mass of white quartz-rock, the equivalent of the upper quartz-rock of the North, which is overlain in both localities by an upper group of schists.

The lowest limestone is seen to the north-east of Islay House, whence it runs for some miles towards the north-east in a broad band. It is a grey crystalline rock, sometimes well bedded, and exactly resembles portions of the Assynt rock. We could detect in it no trace of fossils.

The space between this and the next limestone is probably occupied for the most part by soft schists, as the country is low and covered with peat. The second limestone resembles the first, but appears to be of smaller dimensions.

After another interspace of moor, with here and there exposures of schistose strata dipping towards the south-east, we encounter the third limestone, which follows the curving outline of the escarpment of quartz-rock and plunges sharply below it. This limestone, owing to the form of the island, can be traced further than the others. It extends from Lossit, near the shore of the Sound of Islay, to the Mull of Oe, a distance of 16 or 18 miles. The cliff line at the latter locality affords a good section of the junction of this calcareous seam with the schists below and the strata of quartz-rock above it.

In tracing it northward along the western slopes of the mountains, we find that it has a regular course until within a few yards of the shore of the Sound of Islay near Lossit, where it suddenly wheels round and passes towards the west. By this means it avoids entering the opposite island of Jura, and the superjacent quartz-rock is thus thrown westward along the Islay shores instead of crossing at once with a north-east strike into Jura.

The district between Lossit and Islay House presents a confused, contorted arrangement of the rocks. The various limestones are no longer separable; they seem indeed to become blended more or less into one, and on crossing the central valley towards the north they die out altogether, so that the lower grauwacke-grits and the upper quartz-rock unite. They are considerably mineralized, containing, in at least one locality, veins of lead which are worked.

The upper limestone is surmounted by some schistose strata, well seen at the Mull of Oe, which graduate upward into white quartz-rock. The great mountain-masses of Beinn Bhan, Ben Vicker, and other summits, looking in the distance as if capped with snow, consist entirely of beds of this quartz-rock, having a south-easterly dip at from 30° to 40°. Sometimes, however, the rock has a reddish hue and a coarse granular texture, as along the cliff line of Macarthur's Head, where the strata have been considerably broken. Further to the north it even assumes the character of a breccia, the included fragments consisting of variously coloured felspathic rocks. The upper beds of this quartzose mass descend rapidly towards the east, and are succeeded by a group of schists (with intruded beds of greenstone), which, in alternate ridge and valley, occupies the descending ground between the grey mountain-chain and the eastern shore*.

* Macculloch (Trans. Geol. Soc. vol. ii. p. 413) says, "Extensive and correct

The junction of the quartz-rock with these schists can be seen at many places. Thus the sea has cut some instructive sections near Macarthur's Head, and still more clearly at the Mull of Oe. The streams too which descend from the hills in an easterly direction have laid open many exposures of the rocks. The junction-line of the two series of strata is not a sharp one. The quartz-rock passes, by intercalations of schist, into the schistose group, and the latter, by interstratifications of quartz-rock, into the quartzose group. The structure of this part of the island vividly recalls that of the east coast of the peninsula of Sleat in Skye.

The schists which thus rest upon, and at their base are interlaced with, the quartz-rock vary in character, being sometimes micaceous, argillaceous, quartzose, chloritic, or talcose. These changes of lithological distinction are so rapid that it is impossible to give any one mineralogical name to the group, or to map out its members by mineral characters. Some of the argillaceous beds are quarried for slate in Port Ellen Bay, where they have a rude cleavage. Some of the harder beds of grit which occur among the schists have a greenish colour and a slightly chloritic composition, and (as at Port Ellen) have been worked as building-stones. Sometimes the schists are varied by the intercalation of hard micaceous and siliceous flagstones, which are well exposed along the coast at Ardimersay, the residence of our very kind friend Mr. Ramsay of Kildalton. One thin course of limestone occurs at Kintore.

But the most marked feature of this schistose series is the great number and extent of its hornblendic greenstones. These are grouped in long parallel ridges corresponding to the strike of the strata. They are, however, beyond all doubt intrusive sheets, since they alter the rocks along the line of contact, and do not always conform to the bedding, but here and there cut across it, twisting and hardening the surrounding schists*. The same greenstones occur also in the quartz-rock, but sparingly. Their great development is among the schists, where, along the coast from Port Ellen to near Macarthur's Head, they form the more prominent reefs and islets, to which they give a narrow outline and a north-east and south-west direction.

The whole of the Island of Islay is more or less traversed by a series of basalt-dykes, which range in a general way from north-west to south-east—a direction which characterizes all the later dykes of the western coast of Scotland. These igneous rocks cut across every other rock in the island. Their posteriority to the greenstones is beautifully shown on the coast south of Macarthur's Head, where the long crags of greenstone which run out to sea are crossed by veins of basalt that pass from reef to reef with striking

observations on Isla would probably determine the true relative era of the quartz-rock, and elucidate still further the disposition of Schihallien, of Jura, and of the north of Scotland."

* Since our observations were made, Mr. Jameson of Ellon has examined the geology of the opposite mainland of Cantyre, and found that the schists there are traversed by a similar series of intrusive beds of greenstone, which, as in Islay and Jura, are crossed at right angles by a newer group of basalt-dykes.

persistence. These dykes may be seen high on the sides of the grey quartz mountains, and one is especially observable a little below the summit of Ben Vicker.

The Island of Jura, the magnificent mountain-ranges of which form the deer-forest of our hospitable friend the Laird of Jura, presents no feature which has not been already noticed in the description of Islay. The limestones and lower schistose series are, however, wanting; and the quartz-rock attains a much grander development than in Islay, rising into the Paps of Jura, 2569 feet above the sea. Macculloch has well described the singular and striking view from the summits of these mountains, which altogether constitute the grandest display of quartz-rock to be seen in Scotland*. Nothing can exceed the distinctness with which the lines of bedding are impressed on the cliffs and along the ridges. The whole island seems spread out as in a map, and we can follow almost the line of each stratum as it winds over hill and crag, valley and tarn, among solitudes that are haunted only by the red-deer and the eagle. Here and there among the grey cliffs we detect the dark line of a basalt-dyke pursuing the even tenor of its way towards the north-west, alike over precipitous mountain and deep glen.

The line of schists which fringe the eastern coast of the island correspond to those that occupy the same part of Islay. They are marked too by the same lines of greenstone, ranging into the beds, and are traversed by the same series of later basalt-dykes.

Prolongation of the Islay and Jura Rocks up the Linnhe Loch.— The limestones of Islay, overlain, as we have shown, by a great quartz-rock series, are prolonged towards the north-east in the Garvelloch Isles and the Islands of Lismore and Shuna. The quartz-rock above them, after traversing the length of Jura and Scarba, becomes lost beneath the sea. But we find traces of it again, though in a greatly diminished form, along the eastern shores of the Linnhe Loch, north of Oban. It there occurs as bands of quartz-rock and quartzose flaggy beds among schists, and dips, like the limestones below and the schists above, towards the south-east. The upper schistose series, with its associated limestone bands, skirts the eastern shores of Jura and Scarba, and thence runs towards the north-east, forming, with the addition of later rocks, the chain of islands towards Oban as well as a large part of the mainland.

The crystalline series of strata, therefore, which is so clearly exhibited in Islay, is continued up the Linnhe Loch, the rocks having a steady south-easterly inclination. This line forms one side of the anticlinal arch which has been pointed out as coincident with the direction of the Great Glen, or line of the Caledonian Canal; the other side is lost beneath the Atlantic. In the reverse or north-

* Description of Western Islands, vol. ii. p. 205, &c. See also Trans. Geol. Soc. vol. ii., where he gives other details. His section of the order of superposition agrees with our own. He says that the quartz-rock of Jura underlies the slates, and contains water-worn pebbles, also worm-like cylindrical borings, and that it was "originally a stratified sandstone which has been chemically and mechanically altered." (pp. 454, 455, 462–3.)

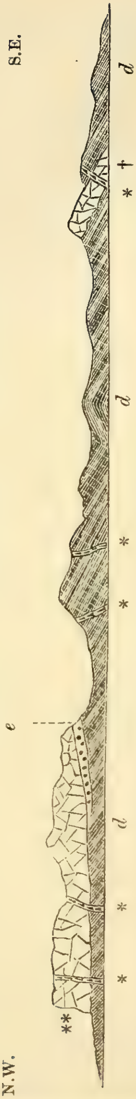


Fig. 21.—*Section of the Island of Seil.* Length $4\frac{1}{2}$ miles.

d. Clay-slate. *e.* Conglomerate. † Greenstone. ** Amygdaloidal Greenstone. * Dykes of Basalt.

westerly dip of the slates at Sanaig Point in Islay, however, we see the beginning of the curve, which is doubtless continued towards the north-east until it joins the line of section already described at Loch Eil.

One or two localities along the north-eastern prolongation of the Islay series were examined by us in detail, and present features of sufficient importance to merit separate notice.

Seil and Easdale.—These islands consist fundamentally of clay-slate belonging to the upper schistose series, and lying on the same general horizon with the schists and slates which range along the eastern shores of Islay and Jura. The slates have a general south-easterly dip, and range into Lorn, but are there buried beneath a mass of later igneous rocks, and partly also under a series of reddish sandstones and conglomerates.

Easdale consists entirely of slate, with the exception of certain N.W. and S.E. greenstone-dykes. Seil presents a greater variety: its north-western half consists of an outlier of the Lorn trap, resting, apparently conformably, on some sandy conglomerates which lie in complete unconformity on the slates. These conglomerates form part of the same series which in Lorn, as around Oban and along Loch Feochan, underlie the igneous rocks and cover over the slates unconformably.

The annexed section, fig. 21, explains the structure of this island. Without cumbering the present memoir with details, it may be enough to remark that the slates vary in dip from S. 40° E. to S. 64° E., and the angle from 25° to 82°. In a line passing a little north-west of Kilbrandon Church, and reaching the north-east shore near some old slate-quarries, there appears to be a slight fold; but, with this exception, no instance was met with of an inclination to north-west. The south-east limb of the island has a strongly marked ridge running parallel to the strike of the strata. It exactly resembles the ridges along the eastern flank of the Islay mountains, and consists, like them, of a magnesian greenstone which has been intruded parallel to the bedding. This rock is traversed here, as in Islay and Jura, by transverse N.W. and S.E. dykes of greenstone or basalt. These dykes also cut through the conglomerates as well as the sheet of greenstone to the north-west. They occur abundantly, too, on the opposite island of Easdale, where they present some interesting features in relation to the different rates at which the various parts of the dykes cooled.

The slates of Easdale and Seil present perhaps the most perfect cleavage yet known in Scotland. The cleavage-planes lie in the same direction as the bedding—that is, towards the south-east—but generally at a higher angle. The following list of observations, taken from Easdale, across the strike of the Seil slates, will show the ratio of the two planes:—

Easdale (south side):	slates dip	S. 62° E. at 32°;	cleavage same direction	at 50°.
" "	"	S. 46° E. at 25°;	" "	45°.
" "	"	S. 64° E. at 68°;	" "	42°.
Seil Harbour	"	S. 54° E. at 82°;	" "	55°.
" (west shore)	"	S. 43° E. at 27°;	" "	55°.
" "	"	S. 40° E. at 33°;	" "	57°.
" "	"	S. 52° E. at 27°;	" S. 42°	E. 42°.
" (1 mile N.W. of Kirk)		S. 60° E. at 60°–67°;	"	60°–70°.
" (old slate-quarries)	"	obscure dip;	" S. 66°	E. 27°–45°.
" (100 yds. N. of last obs.)		S. 60° E. 60°–70°;	" S. 66°	E. 40°.
" (eastern shore)	"	S. 56° E. 25°;	" S. 66°	E. 62°.

The bedding of the slates is distinctly defined both by lines of colour and by the intercalation of seams of hard blue sandy mudstone, nodules of which also occur in the slate. The cleavage is most perfect where the slate is finest in grain; some of the sandy beds are only rudely cleaved, and others show no cleavage at all. The surfaces of the cleavage-planes are finely waved or foliated, and contain numerous cubes of iron-pyrites.

Eastern Shores of Linnhe Loch.—The slates of Seil and Easdale are soon lost in their northward prolongation under the sheets of greenstone and underlying reddish sandstones* that form so large a tract in Lorn. North of Oban, however, we find the quartz-rock or quartzose flagstones rising in terraces along the east coast of Loch Linnhe, especially in the neighbourhood of Port Appin. They are covered by the upper limestones and schists as in Islay, and are clearly underlain by the thick limestone of Lismore. The section at this place therefore forms the counterpart of that of Islay to the south, and that of Ross and Sutherland to the north.

Glen Spean.—The same order of succession continues up the Great Glen, which, as we have already shown, coincides with the line of an anticlinal axis. The quartzose strata which have been described as occurring at the head of Loch Eil, and thence eastwards to Banavie, roll over to the south-east, and are followed by schistose beds containing several seams of limestone. The stream in Glen Spean, on the north side of Ben Nevis, shows the succession well. At the Bridge of Spean, quartzose and schistose strata dip S. 55° E. at a high angle. Quarter of a mile to the eastward, quartzose flagstones, much altered, with intercalations of bluish-grey micaceous and talcose schist, dip S. 62° E. at 65° to 90°. This same quartzose series con-

* The thick-bedded, very hard, greenish, siliceous sandstone on Loch Feochan, south of Oban, is undistinguishable from many portions of the Old Red Sandstone, but may be of later age.

tinues up the glen for about a mile in nearly vertical beds, striking N. 16°–24° E., with a slight inclination to the south of east. The beds are flaggy and micaceous, and sometimes so pulverulent that they might be called sandstones. They are succeeded by a set of flaggy, very micaceous schists, nearly vertical, sometimes quite so, striking N. 44° E. Here a series of bands of grey crystalline limestone occurs, with the lines of stratification well marked, especially where layers of schist 1 to 4 feet broad are intercalated with them. A little higher up the river some dykes of felspathic and hornblendic greenstone occur, striking with the strata N. 34° E.

The same schists continue up the valley, though greatly obscured by deep drift. They are sometimes talcose, sometimes strongly quartzose, but usually micaceous. At the Bridge of Roy they strike N. 45° E. with a south-easterly dip of from 60°–80°.

Here again therefore we are presented, along another line of section, with the same order of superposition. Quartzose strata, corresponding to the upper quartzose flaggy series of Sutherland and Ross and the upper quartz-rock of Islay, pass up into a set of schists which in their lower part contain calcareous seams, exactly as in Sutherland, Ross, and Islay.

Loch Leven.—Between the section just described and that of Port Appin above alluded to, there is an excellent transverse exposure of the rocks along the shores of the maritime Loch Leven. In skirting the east side of Loch Eil from Fort William southward, the passage-beds, so to speak, between the quartzose and the schistose series are seen on the road-side much contorted and broken, but with a general northerly strike and easterly dip. As we approach Loch Leven, thick bands of white quartz-rock are seen to occur in the series; and on reaching the margin of that loch we find the whole plunging sharply to the south-east. A bed of limestone is quarried here, above which lies a thick band of white quartz-rock, and then come the true slates of Ballahulish, which lie on the same horizon with those of Easdale.

The intercalation of white quartz-rock above the limestone and the general interlacing of the quartzose and the schistose series are facts of great importance.

On the south side of Loch Leven the same slates are well exposed. In spite of the granite and porphyry masses which here occur, they have a marked north-easterly strike, and where first seen, though nearly vertical, incline towards the south-east. Gradually they become vertical; and then, among the great slate-quarries, they take a high westerly dip. They are traversed by a cleavage very inferior to that of Easdale, and apparently in the quarries coincident with the lines of bedding. A little eastward, however, on the side of the high road, beyond an archway, there is a good section of the slates, which dip 6°–10° S. of W. at 45°. They are traversed by cleavage-planes which dip in nearly the same direction at 75°. These planes cut through alternate beds, the coarser sandy layers being uncleaved. Immediately under the slates comes a thick band of hard blue and grey compact and flinty limestone, with lighter bands interstratified through its mass. In its upper part it dips 12° S. of W. at about 75° with a rude oblique cleavage. Eastwards the dip changes to nearly S.W., and the angle varies from 50° to 70°. The limestone, with slaty interstratifications, continues to occupy the shore for at least half a mile, when it is underlain by another series of slates and schistose beds towards the entrance into Glen Coe.

Glen Coe.—As we ascend this glen the slates are succeeded by quartzose rocks, and the whole valley is traversed by a network of bands of porphyry. The quartzose strata, however, appear to have a decided westerly or north-westerly dip, which towards the entrance of the Pass of Glen Coe becomes very gentle and then undulates to the S.E. The amount of alteration now becomes very great. Dykes and masses of felspathic porphyry abound, and it becomes difficult to detect the actual bedding of the strata, which are split vertically by a kind of jointing or rude cleavage. Towards the head of the Pass the schists or slates are again met with, but in an intensely altered condition, having passed into lydian-stone or jasper. In spite of this metamorphism, however, we believed that they showed a S.E. dip. Towards King's House masses of granite occur; and the whole of this region, extending eastwards over the wild moor of Rannoch and southwards among the mountains of Cruachan Ben, is eminently metamorphic.

The Breadalbane Forest.—The metamorphic region just alluded to forms part of the great deer-forest of the Marquis of Breadalbane, and is a good centre from which to explore the geology of this part of the Scottish Highlands. A reference to previous geological maps will show that this extensive tract has been coloured as "gneiss" with large areas of granite. In truth, however, the region is not one of true gneiss; nor, so far as we observed, does the granite occur in the large, well-defined areas which have been assigned to it. On the contrary, the same lower quartzose series and upper schistose series form the groundwork here, as in such vast areas of other parts of the Highlands, granite and porphyry occurring abundantly in veins, knobs, hillocks, hills—in short, in every variety of form and size, across the belt of country from Ben Cruachan to Loch Rannoch. North-west of that belt, that is, along the Loch Leven shores and towards Glen Coe, the order of succession is plain;—south-eastward through Glen Orchy and the surrounding country, as we shall immediately see, the order is equally clear; and even in the granitified tract itself we are at no loss to determine along what part of the great Lower Silurian series it lies. There is no trace of any protrusion of the lower or Laurentian gneiss. The stratified rocks indeed, as was pointed out to us on the spot by the noble proprietor, are occasionally hornblendic; but they cannot properly be called gneiss, nor can they for an instant be mistaken for the older gneiss of the North-western Highlands and Islands.

The Moor of Rannoch* may be regarded as an undulating dome

* Macculloch (Trans. Geol. Soc., old ser., vol. iii. p. 129) describes the Moor of Rannoch as a rugged plateau of granite, which extends to the head of Loch Rannoch, or for twenty-four miles, and as "one of the most complicated and

of the quartzose rocks, with here and there perhaps, where the undulations are broader and deeper, an outlier or basin of the schistose series. At the Bridge of Bah, between King's House and Inverouran, the quartzose flagstones have a N.W. dip, and rise from under the highly altered schists of Glen Coe already referred to. The dip varies greatly even at short distances, but from this point towards the south-east the north-westerly direction is on the whole maintained. It is well seen at Loch Tulla, near the Marquis of Breadalbane's Shooting Lodge of the Black Mount, and on the opposite mountains of Ben Or, Ben Doran, Ben Do, Ben-na-chalader, and Ben Chrechan. The south-easterly dip is resumed at the watershed, and eventually towards Tyndrum we return again upon the schists.

Before entering into the details of the eastern side of this great anticlinal arch, we here give the results of an excursion by Glen Orchy to Dalmally, and thence to Cruachan, whereby one of us defined the southward limit of the arch, whilst the other explored, for the third time, from the hospitable centre of the Black Mount.

Black Mount by Glen Orchy to Loch Awe.—The quartzose flagstones of Loch Tulla are well seen in the channel of the stream where the road crosses the Orchy. They dip N. 36° W. at 15°–25°. They are micaceous, the mica being especially abundant along the planes of bedding, whereby a fissility is given to the rocks. About a quarter of a mile below the bridge the same quartzose micaceous strata turn round to due N., but a short way down they resume their dip to N. 26° W. at 20°–30°. Here they are well-marked flagstones, each flag being separated from its neighbours by plates of silvery mica. As we descend the stream the character of the rock continues the same for several miles, but the dip gradually veers round to W., W. by S., and S.W., at the same gentle inclination: by this change the series is slowly repeated; and the beds eventually becoming more and more micaceous, are, in fact, in many places true mica-schist. At Achenafanich, near the bottom of Glen Orchy, a band of white quartz-rock is seen descending obliquely the west side of the valley with a south-westerly dip. It is clearly underlain by some darker micaceous beds and covered by others of a similar kind. At the bottom of the glen, where the two roads meet, schistose micaceous strata dip W. by S. at 25° or 30°. They are traversed by a dyke of augitic greenstone, which runs W. 10° N., rises along the hillside to the north of the Orchy, and crosses the valley at the head of Loch Awe near Stronmelch. In Professor Nicol's Map this dyke is marked as having a N.N.E. strike. A parallel ridge to the south may possibly mark the line of another dyke, but we did not examine it. About a mile and a half before reaching Dalmally some flaggy schistose beds are seen in a brook by the roadside, dipping S. by W.

In the streamlet close to the inn of Dalmally, fissile mica-schist dips S. 16° W. at 55°; and a short way further west, in an old quarry,

interesting districts in the whole range of Scottish geology." This granite extends south-westwards into the shoulders of the mountains to the south of the King's House, where it was pointed out to us by Lord Breadalbane in the old military road of Marshal Wade, and where it is not marked in previous maps.

the strata are highly argillaceous as well as micaceous, dipping S. 50° W. at 42°. At the manse a seam of limestone was formerly quarried. Where the road crosses the Orchy, sandy micaceous schist dips S. 60° W. at 45° to 55°. The same south-westerly inclination continues towards the head of Loch Awe. Beyond Stronmelch, the greenstone dyke already described descends from the hillside and plunges below a drift-covered peaty plain. The strata at the head of Loch Awe seem to be greatly contorted, having in places even a north-westerly dip. Another dyke of greenstone, possibly a prolongation of the second ridge at the foot of Glen Orchy, which we conjectured to consist of greenstone, crosses the road on the west side of the Loch Awe valley a short way south of the point where the road crosses the Main Water. Quarter of a mile from the bridge a streamlet has laid open a good section of some quartzose flagstones, micaceous and chloritic, dipping S. 52° W. at 35° to 40°.

We made copious notes of the section along the western shore of Loch Awe to the outlet of the river, but we need only cite here one or two of the more important facts. The dip, sometimes reversed and frequently varying, maintains on the whole a south-westerly direction, and the strata become very schistose as we ascend in the series. Mica, chlorite, and talc are the distinguishing minerals. About seven miles from Dalmally a bed of hard siliceous limestone occurs, with occasionally a green serpentine colour, and many thin talcose seams. It also contains lenticular masses of white quartz, and dips S. 54° W. at 48°. Above this limestone come several other bands of a similar rock, forming as a whole a thick limestone series. Serpentine abounds, giving the beds a green colour. Felspar-porphyry is also abundant, both in the form of beds parallel to the planes of stratification, and also as veins cutting through the strata irregularly. This porphyry deserves remark. Where disposed in a bedded form, it is traversed by lines of quartz corresponding exactly to the lines of bedding of the adjacent limestones and schists. It contains much talc, which, however, is invisible in the cross fracture, but shows a silvery surface along lines parallel to the bedding-planes. Otherwise the rock appears to consist mainly of pink felspar. The aspect of these porphyries more than once suggested the idea that they were only more highly mineralized portions of the stratified series that had been metamorphosed *in situ*.

The schists with innumerable dykes and veins continue down the Pass of Loch Awe. They appear eventually to be reversed to S.E., showing thus the commencement of the other side of the trough which begins with the south-westerly dip of the strata in Glen Orchy. The granitic region of Cruachan Ben intervenes between the Awe and Loch Leven, rendering a careful examination necessary before the geological lines at these places can be safely joined. In the meantime, however, we regard the synclinal trough of Ballahulish as a continuation of that of the Awe—an inference which the general strike of the strata at both localities and over part of the intermediate ground seems to render probable.

Dalmally to Tyndrum.—The section up the glen from Dalmally to Tyndrum is very instructive. The dyke which has been already noticed as trending in a W.N.W. direction from the head of Loch Awe to the foot of Glen Orchy, runs along the northern side of this glen for about five miles from Dalmally, beyond which we failed to trace it. The schistose rocks, seen where the two roads join, are succeeded by inferior beds of quartzose flagstones, often highly micaceous. These gradually change their dip from S.W. to S., and to S. by E. and S.E. The angle of inclination is gentle (15°–20°), so that the same beds which occur at the top of the hillside on one side of the glen are seen at a lower level on the other, the S.E. side being steeper, since it is the escarpment, and the north-west side more shelving, the slope often nearly coinciding with the dip of the strata. As we ascend, the oblique direction of the glen brings us across the strata in a gradually ascending progression until we arrive again at the micaceous schists. These are seen in the streams around Tyndrum, where they have a marked S.E. dip.

From this section it is evident that the anticlinal arch of the Breadalbane Forest sinks down towards the south below the schists, which curve round the quartzose series in a wide semicircular sweep that extends from the flanks of Cruachan by Dalmally to Tyndrum.

The Black Mount to Tyndrum.—The quartzose flagstones of Loch Tulla ascending into the Ben-Do range have there a marked north-westerly dip, with a gentle inclination of 10° or 15°. Ascending by the road from Orchy Bridge we find the flaggy beds well exposed in ravines and cuttings by the wayside. The north-westerly dip and gentle angle continue until towards the watershed, when the beds begin to incline to the north, then gradually to the north-east and east, until, when the summit of the road is reached, they take a decided south-easterly dip, and a higher angle than on the north-western side. By this means the flaggy beds are repeated, and we speedily pass into the schists that overlie them.

The axis of the Ben-Do and Ben-na-chalader chain strikes towards the north-east into the Brae Lyon mountains. It is, however, only a minor anticlinal fold along the great arch of quartzose rocks, which we have defined as ranging through the Breadalbane Forest from Ben Cruachan to Glen Rannoch, beyond which it stretches away into Atholl Forest and the heart of the Grampian Mountains.

It remains now to describe the disposition of the schists as they fold round the south-eastern side of this great arch.

Tyndrum to Loch Tay.—From Tyndrum down Glen Dochart the schists have a south-easterly dip at from 10° to 15°. They occasionally become highly altered, however, with a more rapid dip. About a mile N.W. from Crianlarich, limestone is quarried. It is a hard, blue, crystalline and fissile limestone with numerous green serpentinous and talcose interlaminations, as at Loch Awe*.

At Loch Dochart the schistose or gneissose strata are much gnarled and twisted, dipping in various directions from N.E. to S.E. The whole of the valley of the Dochart is more or less obscured by drift,

* See this limestone described by David Forbes, Quart. Journ. Geol. Soc. vol. xi. p. 166.

and the rocks are consequently for long distances obscured. As we approach Luib the dip appears on the whole north-easterly. There the beds seem undulating along an E.N.E. axis; but they may possibly be reversed to N.W. Near Luib we saw no rock decidedly in place; but some exposed ledges appeared to have a N.W. dip.

To the north-east of Luib, limestone has been worked on both sides of the glen. The seam appears to run along the north-west side, and is at present quarried on the declivity a short way west of Killin. Below the limestone in the bed of the river, flagstones are seen nearly horizontal, evidently the beginning of the quartzose series.

Thus from Tyndrum to Killin we cross obliquely a synclinal trough of the schists with limestone at either side, below which lie the quartzose flagstones. This trough extends north-eastward by Ben Lawers and Strath Tummel to the head of Glenshee, whence it appears to enter the Grampians. To the south-east it is prolonged by the head of Loch Fyne to the Atlantic at Loch Swene.

*Loch Tay**.—This magnificent sheet of water occupies the line of another anticlinal arch. The limestone just referred to as occurring to the west of Killin, sweeps along the north-west side of the lake, and plunges below Ben Lawers. In reality there are several limestones here, as there are at Loch Awe; but we did not stay to note the details, being satisfied that the whole formed a calcareous group above the flagstones and below the schists. On the south-east side of Loch Tay the limestones also occur, having a south-easterly dip, and passing under the schists, which here, as at Tyndrum, contain the well-known metalliferous veins worked by the Marquis of Breadalbane†.

We are not aware how far the limestones stretch towards the south-west. Those of Loch-Earn-Head appear to belong to another arch. Towards the north-east of Loch Tay they are soon lost, but reappear in the valley of the Tummel at Pitlochrie.

The numerous sections along the side of Loch Tay afford ample scope for working out the details of this region. There is no more beautiful district in Scotland, nor, at the same time, one where the geologist might better acquaint himself with the order of superposition, lithological characters, and mineralogical riches of the younger portion of the crystalline rocks of the Highlands.

Loch Tay to Glen Lyon.—This traverse of the mountain-ridge of Ben Lawers need not be detailed. It shows the limestones of Loch Tay plunging below the schists of the ridge, which are often crumpled and contorted. On the north-west side the dip changes to south-

* It gives us great satisfaction to state that before entering upon our labours of the last summer, Professor Harkness had the kindness to furnish us with coloured sections made by him during an earlier part of the same year, of part of the country to the south-east of the line of the Caledonian Canal. His researches were, we found, in complete harmony with our own; and his section of Ben Lawers especially was of great use to us. He has since further extended his observations into the North of Ireland, and found there the same order of succession among the crystalline rocks, as will shortly appear in a paper communicated by him to the Society.

† See Quart. Journ. Geol. Soc. vol. xvi. p. 421, &c.

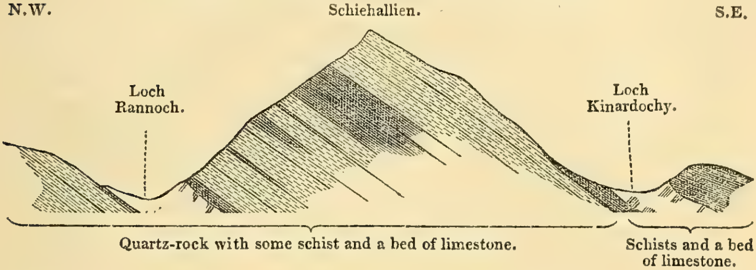
east, and the crumpled schists are repeated, until at Glen Lyon the limestone emerges from below them, followed in its turn, as usual, by the quartz-rock. Thus the enormous mass of Ben Lawers, like many other mountains in Scotland, as well as elsewhere, actually occupies a synclinal trough, while the deep valley of Loch Tay, like that of the Great Glen, runs along an anticlinal arch.

Loch Tay to Loch Rannoch.—The mountainous road from Kenmore, by the north-east flank of Schiehallien to Loch Rannoch, affords a cross section of the upper schistose beds in their prolongation along the synclinal axis of Ben Lawers, with the limestone below them and the underlying quartz-rock, to perhaps a greater depth than any other locality in the Central Highlands. The north-west dip of the schists continues for some miles beyond Kenmore. At the waterfall close to the road, north of where it crosses the River Lyon, the dip is N. 16° to 30° W. About a mile south of the White-bridge toll-gate the dip changes again to S.E., forming thus the north-western side of the trough. As we proceed, we find the limestone rising again in great force from under the schists. It is quarried at the end of Loch Kinardochy, where it resembles the Loch Tay limestones, but is greatly contorted. We believe that from this point it ranges across Strath Tummel, and joins the great limestone series of Blair-Atholl, with which it is undoubtedly identical. Following that branch of the road which strikes to the left towards Rannoch, we come to grey micaceous flagstones dipping S. 26° E. at from 55° to nearly 90°. Veins of a red felspar-porphyry are not unfrequent. About four miles from Loch Rannoch, after passing over a great thickness of quartzo-micaceous flagstones, the road enters a thick zone of limestone, which when first seen is covered by dark silky schists, and has a S.E. dip. It soon rolls over, however, and appears to undulate, often in sharp folds, for a long way, after which the ground becomes obscured by drift until Kinloch Rannoch is reached.

The section along the north side of the valley eastward from Kinloch Rannoch shows that quartz-rock, sometimes as thick-bedded and brilliantly white as that of Sutherland or of Jura, sometimes flaggy and micaceous, underlies the limestone. Near the inn, the flagstones dip E. at 55°, and are probably intermingled with syenite, large blocks of which strew the hillside. At Drumihastle the limestone occurs again, having crossed the valley of the Rannoch, and it here dips E. 8° N. at 65°. It is flaggy and finely laminated, and is associated with dark schists, as on the south side. Above the limestone, white quartz-rock and flaggy beds supervene.

The subjoined figure represents the section from Loch Kinardochy to Loch Rannoch. It will be seen that the limestone at the former locality lies below schists, and, as we have seen, represents the calcareous bands between the schists and the quartzose series on Loch Tay, and indeed throughout the whole Highland region. Below this limestone come the usual quartzose strata. These form the higher part of the giant Peak of Schiehallien. But they are here underlain by a thick limestone, and that by another quartz-rock group—a much more complete series than appears to occur anywhere else east of the line of the Caledonian Canal.

Fig. 22.—*Section of Schiehallien, Perthshire.*



At the time when our observations were made, we believed that in this second limestone we had found the prolongation of the great lower calcareous zone which in Sutherland and Ross, as well as far to the southward, in Islay, subdivides the quartzose group into an upper and an under series. The extension of our survey to the north and to the east served to confirm this inference. We found the limestone as it stretched northward become thinner, until, not far beyond Glen Erochie Inn (above which, on the north side of the valley, it has been worked), it appears to die away altogether; and it does not occur in the consecutive section along the channel of the River Garry.

Here, then, along the great anticlinal axis of the Breadalbane Forest already described, there is a lower part of the series brought up than at any other locality throughout this tract. It is important to remark, too, that the greater extent of the curve only serves to bring up strata already known in other districts, and which could have been confidently predicted to exist here, as soon as it had been ascertained that there occurred a lower set of beds than the flagstones of the Black Mount. Thus confirmatory evidence is obtained of the correctness of the present explication of the order of succession throughout the Central Highlands.

*Dalnacardoch to Blair**.—As the road winds over the hills from Glen Erochie to Dalnacardoch, a marked dyke of porphyritic felstone with hornblende strikes through the limestone and the micaceous flagstones in a nearly north and south direction, and runs for a long way northward. It occurs again in the bed of the Garry, at Dalnacardoch Inn, and on the hill above the road, with a breadth of 15 or 20 feet and a strike from S.S.W. to N.N.E. How much further north it extends we did not ascertain.

There is an admirable section of the quartzose series along the bed

* This tract, according to Macculloch (Trans. Geol. Soc. 1st series, vol. iii. p. 297), is wholly, or in great measure, composed of hard argillaceous schist, graduating into argillaceous quartz-rock, and more rarely into mica-schist, with granite-veins here and there dispersed through it.

of the River Garry, both above and below Dalnacardoch. Above the inn, the quartz-rock, in well-bedded fissile flagstones, dips to the S.E. at an average angle of 30° to 35°. Several small dykes of felspar-porphyry, running along the strike of the beds, occur about three-quarters of a mile to the north-west of Dalnacardoch. The south-easterly dip continues for three miles up the Garry, though towards the end of that distance it becomes subject to undulations, showing that the strata are on the eve of turning over in an opposite direction. This reversed or N.W. dip is well seen in the channel of a torrent on the right-hand side of the glen, about three miles north of Dalnacardoch. There, grey flaggy quartz-rock dips N. 42° W. at about 30°. The stream has brought down an immense quantity of shingle from the hillsides, chiefly of grey quartz-rock, with not a few fragments of reddish felspar-porphyry. Above this, the bottom of the valley is drifty and alluvial; but the colour and form of the bounding mountains left us in no doubt that the same quartzose series extends northward beyond the Pass of Drummuchter.

The descent of the Garry from Dalnacardoch exhibits a clear ascending section of quartzose flagstones, occasionally schistose and micaceous. The dip is as nearly as may be S.E., and the angle ranges from 25° to 60° or 70°. Even allowing for some reduplications, the thickness of this series must be very great. Here and there, as at $5\frac{1}{2}$, $4\frac{3}{4}$, and $4\frac{1}{4}$ miles respectively from Blair, dykes and masses of felspar-porphyry occur, with a general strike from N. by E. to S. by W. Two miles and a half from Blair the series is terminated by the superposition of a very thick limestone series.

Blair-Atholl and Glen Tilt.—In following out the curvatures and breaks of the rock-masses and their reappearances in a regular sequence as we proceeded from the north-west to the south-east, it was evident, from proofs of superposition only, that when we came to the south-western flank of the Grampians we had once more reached the upper crystalline series. On a former occasion a similar ascending succession to the younger stratified crystalline schists, whether micaceous, quartzose, or chloritic, with bands of gneissic character and argillaceous slates, had been traced from the heart of Ross and Inverness to the northern, eastern, and south-eastern flanks of the Grampians, as seen in the counties of Moray, Banff, Aberdeen, Kincardine, and Forfar*. To the last of these tracts we shall presently advert.

In examining the south-western flanks of the Grampian chain near Blair-Atholl, it was indeed quite manifest, judging even from the flaggy and schistose characters of the rocks, that we were already among strata superior at all events to the lower quartz-rock and limestones of the north-west. Glossy shillat with micaceous schists, resting upon granular quartz-rocks and limestones, and even alternating with them, presented to the eye a mineral development unknown in the lower members of the altered Silurian rocks of the North-west, and wholly unlike anything in the Cambrian rocks and fundamental gneiss of the outer Hebrides and the west coast of Sutherland.

* Quart. Journ. Geol. Soc. vol. xv. p. 389 *et seq.*, and vol. xvi. p. 237, &c.

We were now upon the ground rendered classic by the researches of Hutton, Playfair, and Webb Seymour, in which, with the memoir of the last-mentioned of these eminent men in hand, we had only to admire the truthfulness of their descriptions *, which show, even down to the minutest details, the infinite ruptures of such strata, their divergent directions, and their varied phases of metamorphism, when in contact with or in the proximity of the syenites and greenstones of the region.

In fact, Playfair and his associate Lord Webb Seymour had here collected specimens which in one and the same escarpment on the left bank of the Tilt (not exceeding 600 feet in height) offered proofs that granular limestone and quartz-rock were surmounted by mica-slate and gneiss, the latter again alternating with thin quartzose bands. The great variety of compound rocks detected by these close-searching explorers, from a small area on the banks of the Tilt and its affluents, at once demonstrated to us that along the flanks of the Grampians there exists a richness and variety of mineral development which is unknown in the oldest members of the series to the north-west. Thus, Lord Webb Seymour cites many compounds of quartz, mica, felspar, hornblende, actinolite, compact dolomite †, talc, steatite, and serpentine, mixed in a great variety of combinations and in different proportions ‡.

In the same tract of Glen Tilt we saw cause and effect admirably displayed, as pointed out by Hutton, Playfair, and Seymour. With bosses of granite, syenite, and porphyry at hand (mere spurs, however, of the gigantic granitic and porphyritic masses of the Grampians) we at once understood how some of these younger crystalline strata had been converted into the gneiss of the above-mentioned authors, and had become associated here and there with granular quartz-rock and limestone, in which the signs of their having been originally sandstones and calcareous mudstones could not be doubted.

The numerous disruptions in the tract east of Blair-Atholl have thrown the strata into a multitude of fragments, as will be best understood by referring to Lord Webb Seymour's diagrams, and particularly to plate 20 of his Memoir, in which upwards of forty cases of the strike § and dip of the beds are given. Whilst most

* Not having with us the memoir of Lord Webb Seymour, we were indebted to the Duchess of Atholl for the loan of it; whilst the Duke laid open to us the recesses of Glen Tilt by giving us as our guide his head-forester.

† Lord Webb Seymour notes that compact dolomite is found in Glenelg and Kintail. We also found there so much actinolite as to form, in fact, actinolite-schist, with much talcose schist as well as granular limestone. It will therefore be seen that the superior position we have assigned to the rocks of Kintail, Loch-alsh, and Glenelg is borne out by their mineral characters also and their similarity to the rocks of Glen Tilt.

‡ Trans. Roy. Soc. Edinburgh, vol. vii. p. 317.

§ The word '*stretch*' has been used by these eminent Scottish geologists to signify the direction as at right angles to the dip of the strata; and we almost regret that, unmindful of the earlier employment of this appropriate term, one of us, in unison with Professor Sedgwick, was the first to recommend the adoption of the word *strike*, from the German "Streichen" of German geologists. See Trans. Geol. Soc., 2nd series, vol. iii. p. 377 (note).

of these masses preserve the normal strike of N.E. and S.W., with considerable deviations, however, to the N. and S. of E., there are examples of east and west directions; and we meet with others (particularly high up the Tilt, between the Clochan and the Tarff) where the strata striking from S.E. to N.W. are there placed at right angles to the direction of the normal masses. This takes place where intervening syenitic and granitic rocks occur, the stratified rocks being arranged with divergent strikes and dip around such amorphous bosses.

In fact, it is sufficient to ascend the Banavie Burn from the Castle of Blair for half a mile to see every possible discordant break among strata of limestones and schists which have been penetrated by porphyritic and syenitic rocks.

We do not pretend to have succeeded in unraveling the geological structure of this most difficult and intricate region. There are probably some powerful faults, whereby parts of the series are repeated, while other portions are concealed from view; but we could not satisfy ourselves as to the exact position of any one dislocation. Besides faults, however, the district is greatly complicated by the curvings and twistings of the beds, so carefully and completely investigated by Playfair and Webb Seymour*, and by Macculloch†.

We are unable to decide what relation the limestone of Loch Rannoch and Glen Erochie bears to that of Inverveck—the point where limestone is first seen in descending the Garry. If we could succeed in identifying them, probably a great part of our difficulty would be removed. The rock at Inverveck on the south-west side of the Garry, $2\frac{1}{2}$ miles from Blair-Atholl, is a white, grey, or greenish crystalline rock, sometimes almost a steatite, with pale leek-green, talcose laminæ. The strata are much broken, but the dip is on the whole south-easterly.

In the grounds of the Duke of Atholl, especially along the classic Glen Tilt, good sections are obtained of parts of this limestone series, traversed by veins of granite and porphyry. There is much local disturbance and great metamorphism at this locality. Nowhere can this be better seen than in the deep wooded dell of Glen Banavie, immediately behind Blair Castle. We first encounter dark schists, greatly hardened and traversed by dykes of felspar-porphyry, which have a N.N.E. strike. The strata have here no determinate dip; indeed, the bedding is almost obliterated. Higher up, however, the disturbance lessens; and eventually the usual flagstones set in, with a steady south-easterly dip at 25° or 30°.

* Trans. Roy. Soc. Edinburgh, vol. vii. p. 303.

† Trans. Geol. Soc. vol. iii. See especially Macculloch's admirable description of Glen Tilt (*loc. cit.* p. 297). He speaks of granite having a foliated structure, and of that structure being especially observable in the vicinity of quartz-rock. He dwells particularly on the distinction between quartz-rock and gneiss (p. 294), and shows that in Glen Tilt the general series consists of mica-slate alternating in a very irregular manner with hard argillaceous schist and quartz-rock, and with a few beds of limestone (p. 291). The syenite and greenstone of Playfair and Webb Seymour are called by him granite.

We ascended Glen Tilt as far as the Forest Lodge, where one of us climbed the precipitous hill that forms the eastern side of the glen. The whole of this region has been so minutely described by the fathers of Scottish geology that we shall not venture to offer any details, further than that the section of the east side of the glen, opposite the Forest Lodge, shows very clearly that the limestone, after sundry intercalations of schist, is overlain by a thick, massive, white quartz-rock. This rock ought to be found in the Garry, but we could not detect it, unless the hard thick-bedded grey quartz-rock at Ault Clune, two miles below Blair, be its representative.

In the valley of the Garry at Blair and below it, there are probably at least two zones of limestone, one underlying the quartz-rock, as does the limestone of Loch Rannoch, as well as that of Glen Tilt, the other overlying the quartz-rock, like that of Loch Kinardochy; but the whole of the sections in this part of the river are very obscure*.

Blair to Dunkeld.—Passing over the obscured and doubtful ground in the valley of the Garry below Blair-Atholl, we eventually meet with quartzose and schistose strata, considerably contorted; they are seen here and there in the bed of the stream, particularly at the bridge above the romantic Pass of Killiecrankie. About three miles and a half below Ault Clune, they change their dip from S.E. to N.W. The series is then repeated; and at Pitlochrie the limestone comes up again. From this point the latter rock strikes across the hills in a north-easterly direction across Strath Ardle to Glenshee, and thence into Glen Isla. How far it extends to the south-west we did not ascertain. At the Pitlochrie quarry, the dip is N. 10° E.

The valley south of Pitlochrie, judging from the scanty sections to be seen by the wayside, appears to run for two or three miles upon the flagstones that underlie the limestone; two miles south from that village a quarry has been opened in a micaceous quartzose flagstone, which there dips N. 30° E. at 15°; and similar strata are occasionally seen in the channels of the smaller streams that descend into the Tummel. These quartzose strata probably roll over again to the south-east; for we soon come upon the schists. But the valley is much obscured by alluvium, especially after the junction of the Tummel with the Tay; and the time at our disposal did not allow of excursions on either side of the Strath, to settle the relative boundary-lines.

At Dunkeld the upper schistose series is displayed in force. The great quarries south of Birnam have been opened in grey slate, the beds of which dip N. 70° W. at 65°, and are traversed by a cleavage (much less perfect than that of Easdale), the planes of which are inclined in the same direction at 55°.

* Since our observations were made, we have communicated with Prof. Harkness, and have found that he has detected the upper limestone skirting the flanks of the Ben-y-Gloe Mountains, not far above Blair. His observations on this district will form part of the paper already alluded to. As shown in the text, we also met with the upper limestone at the Spittal of Glenshee; but this is at a considerable distance from the Garry valley.

The cuttings of the Dunkeld Railway have shown the junction of these slates with the overlying Old Red conglomerates. The slates are there considerably twisted, and their edges are covered by a conglomerate, which consists mainly of felspathic matter, the pebbles being for the most part rounded and subangular pieces of various amygdaloidal and porphyritic felstones. It was evident at a glance that these pebbles of igneous rock were not derived from the Grampians, since they differed lithologically in a marked degree from the felspathic rocks of the crystalline region. Another fact readily observable was the great scarcity, in places the entire absence, of any fragments of the metamorphic rocks of the neighbouring mountains, or even of the slates on which the beds of conglomerate rest. The inference we formed was, that these conglomerates were derived from volcanic ejections during part of the Lower Old Red Sandstone period; and this was speedily confirmed by finding, interstratified with the conglomerate, a band of dark compact amygdaloidal felstone, above which the conglomerate became exceedingly coarse, and contained large detached masses of this same felstone. The strata become finer as they recede from the junction with the slates, and to the south pass gradually upwards into sandstones.

Spittal of Glenshee to Blairgowrie.—The last traverse which we made this summer was from the Spittal of Glenshee, down that glen, to Blairgowrie and Dunkeld. From the Spittal a glen called Glen Beg branches off to Braemar in a N.N.E. direction. Its western side is formed by a line of limestone which also ranges south-east for nearly a mile. It resembles the limestone of Blair, and, like it, is interstratified with talcose, chloritic, and micaceous schists. Some of these schists are carbonaceous, losing 15 per cent. of their weight after ignition*, and present a remarkable wavy bedding, with foliated surfaces, and a kind of rude cleavage. The number of different bands of limestone is great in this locality, and their changes of dip and strike endless. With a tolerably persistent N.N.E. strike, they overlie the Ben-y-Gloe quartz-rock, and range up Glen Beg, crossing the watershed, and descending again to Braemar. Syenite and porphyry abound, in the form of large amorphous masses or dykes and veins.

On the east side of Glen Beg, the beds at the watershed have a marked S.E. dip, which continues also in the quarry about a mile nearer the Spittal. But much careful work is needed in this highly altered region before its geological details can be thoroughly understood. Limestone, with a northerly dip, has been quarried two miles south of the Spittal, the intermediate ground being occupied by gnarled schists.

Much felspathic rock (syenite or porphyry) occurs on both sides of the glen. The strata become very quartzose, in gentle undulations, as we proceed southwards; and at Lair, a small cottage about two miles from Dalrelzian, they are micaceous flagstones, dipping S.E. at 8°.

* These schists will be referred to in a subsequent paper, in which we propose to indicate the distinction between foliation and cleavage. The carbonaceous schist was analysed by Mr. Tookey of the School of Mines.

At Dalrelzian, limestone is again quarried. This band has a westerly dip at the quarry; but its general range is from S.W. to N.E., as it occurs in Strath Ardle, south of Kirkmichael, and crosses by the southern flank of Mount Blair into Glen Isla. It is succeeded by gnarled schists, and these again at the Bridge of Cally by slates, which have a decided S.E. dip at a high angle. In a short distance, however, the slates take a north-west dip, as they do at Birnam; and at Rattray, a little north of Blairgowrie, they are overlain by the conglomerate of the Old Red Sandstone.

Eastern Flanks of the Grampians.—It was a special object of one of us in a former year to re-examine the schistose rocks on the eastern flanks of the Grampians in Kincardineshire and Forfarshire. This was done in two traverses on different parallels in 1827 and in 1859; and in both of these the succession was found to be similar. In fact, a perfect conformity between argillaceous schists with some limestone, and certain micaceous schists lying nearest to the interior of the chain, was found to prevail. Numerous bosses of porphyry, not laid down on any map, were also observed; and around these granitic, syenitic, or other amorphous rocks, the highly broken strata assumed a gneissic character.

Any one who is acquainted with those localities, *i. e.* the valleys of the Bervie Glen, west of Laurence Kirk, of the North Esk, the Prosser, and South Esk, and will now read our descriptions of the superior schistose and slaty rocks with limestone in the south of Islay, cannot doubt that on the east flank of the Grampians we have a repetition of the upper portion of the same great series, the different members of which we have traced in vast undulations from N.W. to S.E. In fact, the detailed and faithful description of the transverse valley of the North Esk by Colonel Imrie, which was read in the year 1804 *, may be still referred to, after so long an interval, as being in itself a full and copious illustration of our upper series; though, when that paper was written, the author, as well as most of his contemporaries, believed that all such Grampian primary schistose strata had been accumulated at a period long anterior to the existence of life upon the surface of the globe.

In this section we also meet with the valuable proof that all the so-called slates were in truth layers of subaqueous deposit, inasmuch as they alternate over and over with what Colonel Imrie called his "aggregate rock," or, in other words, strata of broken materials accumulated in ancient seas. As this section was examined on foot by one of us in company with Professor Sedgwick in 1827 and found to be quite correct, we now see how completely the facts accord with all our subsequent observations on other flanks of the Grampians.

Whilst on this occasion we are unprepared to enter into a detailed description of the Grampians, we feel assured, from examination of the flanks of these mountains on many points of the compass, that the strata which there exist belong, on the whole, to the upper members of the crystalline stratified rocks of the Highlands, with

* Trans. Roy. Soc. Edinburgh, vol. vi. p. 1.

here and there an emergence of the quartz-rocks and limestones, and that the granites, syenites, porphyries, and other igneous rocks, which occupy so large a portion of the chain, are necessarily of comparatively young age. We have indeed completely satisfied ourselves, by ascending to the heights of Braemar on the one side, and by entering into the heart of the chain from Aberdeen to Balmoral on the other, that whilst there are no clear proofs of the existence of any altered rocks of even the lowest Silurian age, there are certainly not in these mountains any strata of the Cambrian date, and still less any traces of the fundamental gneiss of the North-western Highlands and Islands.

The old notion, therefore, that the Grampians contain the nucleus of the most ancient rocks in Scotland, must now be abandoned.

Appendix. By Sir Roderick I. Murchison.—*February* 6, 1861.

A memoir by Professor Nicol having been read before the Geological Society on the 19th December last, in which the author exhibited several sections illustrating the relations and succession of the stratified crystalline rocks of Sutherland, which were directly at variance with the sections of the same localities which had been published by myself (and confirmed by the observations of Professors Ramsay and Harkness), I then explained, *vivâ voce*, how I conceived that Professor Nicol had been misled by assigning much too great an importance to what I considered to be local and partial disturbances only. I argued that local interferences of eruptive rock in nowise set aside the broad data I had for several years been accumulating, which prove the existence of a fundamental gneiss, as distinguished by *infraposition, direction of the strata, and mineral characters* from all the crystalline schists which overlie those quartz-rocks and limestones that rest upon such older gneiss. Professor Nicol, on the contrary, adhering to the views of the older Scottish geologists (as represented in former maps of Scotland, and his own), considers vast masses of the rocks which I ranked as overlying, to be simply the older gneiss brought up to the surface, and placed in apparently overlying positions by enormous upcast-faults. As his memoir has been published in the Journal of the Geological Society*, I am bound to place on record that I hold distinctly to the general accuracy of those sections which I published; and, believing that the alterations in them proposed by Professor Nicol are either erroneous or founded on deceptive local appearances, I consider that all his reasoning as founded thereon must fall to the ground.

I will here advert to those sections of Professor Nicol which are most important.

First, let us examine the section from Loch Eriboll (p. 92, fig. 5), which passes across the ridge to the east of Eriboll House; since this is the very traverse made by Professors Ramsay and Harkness, as well as by myself. In that diagram the author exhibits much which

* February 1861, vol. xvii. No. 65, p. 85, &c.

is not to be seen between Eriboll House and the summit of the ridge. The section is compiled from some disturbed beds which he observed in a ravine at a certain distance on the strike of the formations, and he thus introduces, beneath the real and visible section, in which all the strata of the escarpment of the ridge are seen to dip to the E.S.E., an ideal subterranean complication. In doing this he commingles the existence of a great fault with a stupendous underground twist of the fundamental gneiss, which rock is not seen nearer to this spot than five or six miles, and which at that distance has a strike entirely discordant to the quartz-rocks there lying upon it. Yet this deep-seated granitic and hornblendic gneiss has, it is suggested, not only changed its direction, and been thrown up conformably *on* the quartz-rock and limestone with a south-easterly dip, but has also been transformed into a micaceous and chloritic schist, wholly unlike any portion of the old gneiss!

My conviction therefore remains unaltered, that, excepting local and partial disturbances, and the irregular intrusion of igneous rocks, the order above Eriboll House is absolutely that which has been published by myself and witnessed by my associates*. It demonstrates, in short, a true ascending order and transition from quartz-rocks and limestone below, into superior micaceous and chloritic schists (upper gneiss), as first indeed observed thirty-three years ago by Professor Sedgwick and myself at this very spot.

Secondly, Professor Nicol has brought forward sections across the strata at points where they are much broken and affected by local intrusion of igneous rocks (notably figs. 3, 4, and 6, pp. 88, 89, 93), in order to show that the intrusive rocks occupy such a place as to indicate a line of great dislocation along which the older gneiss has been heaved up to the surface. But this view has been shown, in former memoirs as well as in the present communication, to be unfounded, inasmuch as similar igneous rocks (felspar-rocks, porphyries, and syenites) re-occur at various horizons in the series of crystalline rocks, and do not invalidate the general ascending order, or change the general conformity of the strata.

Thirdly, at Assynt (see fig. 8, p. 96), the ascending section from the Loch, as given by Professor Nicol, is made to terminate with a limestone above the quartz-rocks; it being held by him that there is no quartz-rock above the limestone, except such as is brought into that position from beneath by upcast-faults. Now, in my own section of the same locality†, an upper quartz-rock is shown to lie conformably upon, and to succeed regularly to, the limestone; and in confirmation of the accuracy of this fact, and of the clear proofs of a passage upwards from that limestone into a superior quartz-rock, I have not only the testimony of Professors Ramsay and Harkness, as previously cited, but that of Mr. Geikie, who, unaccompanied by me, visited the same spot last summer, and saw unmistakeably clear

* In fact, if Prof. Nicol's section be viewed as respects the portion of the strata which can alone be seen, it is almost identical with my own. (See Prof. Harkness's section, Quart. Journ. Geol. Soc. Aug. 1859, vol. xvi. p. 231, fig. 9.)

† Quart. Journ. Geol. Soc. Aug. 1859, vol. xvi. p. 217, fig. 3.

evidence of the existence of an upper quartz-rock, under which the limestone passed without any break *.

Fourthly, I simply repeat the statement I previously made, that there are the most essential distinctions between the old and fundamental gneiss of Loch Stack and Loch More on which the quartz-rock and limestone repose, and the earthy and slightly micaceous flagstones which overlie such rocks on Loch More, and specimens of which to compare with the older gneiss are exhibited. See Professor Nicol's section, fig. 6, and my section, vol. xvi. p. 226, fig. 6. Here again the strike of the old or Laurentian gneiss (a) is nearly at right angles to that of the overlying flag-like schists (d^1) with which Professor Nicol unites it.

Fifthly, I am compelled to point out, in defending the correctness of my own views as regards the relations of the rocks in Durness, that the second of the sections of Professor Nicol (p. 87) is, on the face of it, very inaccurate. The author gives this line of section as proceeding from Far-out Head on the west to Kean-na-binn on the east. Now the fact is, that this line is really from N. by W. to S. by E. (see Map of Sutherland and Admiralty Charts). Owing to this error, the strata are necessarily placed in false positions; for those of the Far-out Head, and the promontories extending to the Bishop's Castle, and which dip away *to the east*, are, as I have shown, the overlying thinly laminated schists with white sandy micaceous flagstones †, and are quite distinct, by position as well as structure, from the nearest old granitic and hornblendic gneiss, which, striking from N.N.W. to S.S.E., dips to the S.S.W.

Sixthly, I would observe, that the section fig. 9, p. 100, from Cnoc Chaorinie to Alt Ellag, as given by Professor Nicol, seems essentially to sustain the proofs of the order of succession which I have pointed out; for in it we see a lower quartz-rock and limestone followed conformably by overlying quartz-rocks and limestones, whilst these are succeeded, also conformably, by chloritic schists. The only difference between this section and my own view of the succession in that tract is, that neither my companions nor myself ‡ could observe the fault or dislocation § which Professor Nicol has

* See also Prof. Harkness's sections in my memoir, Quart. Journ. Geol. Soc. Aug. 1859, vol. xvi. p. 221, fig. 4, and p. 223, fig. 5.

† Specimens of these thin flag-like sandy schists from this promontory were exhibited at the Meeting to show their entire dissimilarity to the old gneiss of Kean-na-binn and the ridge S. of Durine Inn, with which Prof. Nicol connects them.

‡ Professor Ramsay sedulously explored this locality by himself.

§ In a letter recently addressed to me by Professor Harkness, in which he points out other errors in the sections of Professor Nicol, which I do not here mention, he thus alludes to the introduction by Professor Nicol of the fault near Alt Ellag between the quartz-rocks and the overlying chloritic, micaceous, and gneissose rocks:—"Of this fault suffice it to say, that there is not the slightest evidence of any crack here." It has naturally given me great satisfaction to have the support of such an able and independent observer as Professor Harkness, who, when he visited the west of Sutherland, after a discussion which had taken place on those very points at the Aberdeen meeting of the British Association, had, as he himself writes, "a stronger feeling towards Nicol than yourself, so that I may be said to have to some extent prejudged the case; when, however, placed between the quartz-rocks and limestones and the overlying chloritic and somewhat gneissic schists.

In referring to the concluding pages of Professor Nicol's last memoir, I must remind him, that, when he calls for more proofs of the continuance of the ascending order through the central and more easterly parts of Sutherland and Ross than have as yet appeared, he ignores what I have published on those very points. In 1858 I gave a section from Loch Eriboll across the Moin to the Kyles of Tongue, and in the following year I traced the ascending order with Professor Ramsay from the inferior quartz-rock and limestone through overlying micaceous schist into *gneissic* rocks, the latter being invariably most prevalent when in the neighbourhood of eruptive masses of granite and syenite. It was on that occasion that we first ascertained that Ben Stomino (which in Professor Nicol's map is represented as Old Red Sandstone) was a granite. We had therefore already answered Professor Nicol's present query, and had shown that "the huge syenitic domes of Ben Loaghal and Ben Stomino do not break the series, and bring it under the lower and older gneiss*." Again, Professor Nicol writes as if Strath Oikel had not been examined, though that tract was specially cited by myself as proving an ascending order; and when he says that no one has been in the fastnesses of Fannich Forest, I may refer him to my own description of a great north-westerly fold of the overlying strata on Loch Fannich †. In fact, if geologists will only take the trouble to read my memoirs of 1858 and 1859, as published in the Journal of the Geological Society, they will find many other proofs of the continuity of the ascending series to the eastern parts of Ross-shire, and of their intense metamorphism and gneissic characters when in contact with granitic rocks.

As Professor Nicol has endeavoured to show that my sections are inaccurate, I may be permitted to point to the great discrepancy between his earlier sections, published the year after he accompanied me (his first visit to Sutherland), and those on which he now relies. Denying as I do the accuracy of the last, I affirm that some of his first or original sections are quite correct; indeed they entirely agree with my own ‡. First, in the west of Sutherland, he shows, as I have done, a fundamental gneiss (*a*), a red sandstone (*b*), quartz-rocks and limestones, and a conformably overlying "upper gneiss" [*sic*] (*f*) above the House of Eriboll. Yet now he has composed the very different diagram for the same spot, and on that

I saw evidence so clear, I at once adopted your conclusions." Professor Harkness thus concludes his letter:—"The observations which I have since made, both in other parts of the Scotch Highlands, and in the north of Ireland, have still further corroborated your conclusions; and, with reference to the hypothetical views you expressed, I am convinced that the whole arrangement of rocks from the fundamental gneiss to the upper gneissic rocks, &c., as recorded in your memoirs, is the true sequence of the strata which make up the older sedimentary series of the Highlands of Scotland."

* See Prof. Nicol's Memoir, Quart. Journ. Geol. Soc. vol. xvii. pp. 112, 113.

† Quart. Journ. Geol. Soc. vol. xv. p. 387.

‡ See Quart. Journ. Geol. Soc. vol. xiii. pp. 22, 23.

diagram I have already dilated. Next, in his old sections on Loch Broom, his order of the quartz-rock and limestone, conformably overlain by his "upper gneiss," is equally clear, and is entirely in unison with the section made by my companion last summer and with my old observations. In short, his "older gneiss" lying beneath all the other rocks is *a*, and his "upper gneiss" (*b*) is high in the ascending series.

I say, therefore, in citing his own observations and sections, that there is an "upper gneiss;" and to whatever "old, long-established principles of Scottish geology" Professor Nicol may appeal, I maintain that the researches of my contemporaries and myself have necessarily led to the establishment of the new classification.

In conclusion, I may say, that our labours during the last summer, as detailed in the preceding memoir, seem to me to have determined the question at issue, by an appeal to the order exhibited over other and very extensive Highland regions. Thus, Mr. Geikie, taking up the survey of the mainland, whilst I was exploring the Laurentian gneiss of the Lewis, has followed the disputed line of junction from Sutherland through mountainous tracts of Ross-shire for more than sixty miles, and, by observing closely a number of transverse sections, has completely established the proofs of a *regular and unbroken ascending order* from the inferior quartz-rock and limestone into overlying quartzose and micaceous strata (occasionally assuming gneiss-like characters), which, graduating up into chloritic schists and clay-slates, occupy such vast breadths of the north of Scotland. On my own part, I have, during last summer's survey with my associate, so satisfied myself of the existence of the same ascending order, not only in many parts of my native county of Ross, but also by researches in the Southern Highlands, and notably in Islay, as explained in the preceding memoir, that, being now convinced that the principle of classification I suggested is established on a sound basis, I take my leave of the subject, trusting to Mr. Geikie and my other able colleagues of the Geological Survey, as well as to Professor Harkness and younger geologists than myself, to discover new truths, which may improve or modify my conclusions.

On the Coincidence *between* Stratification *and* Foliation *in the* Crystalline Rocks *of the* Scottish Highlands. By Sir Roderick I. Murchison, D.C.L., V.P.G.S., F.R.S., &c., and Archibald Geikie, Esq., F.R.S.E., F.G.S.

[Read February 20, 1861, but, by permission, printed here in association with the foregoing paper, which has reference to the same country.]

No memoir on the crystalline rocks of the Highlands of Scotland can be regarded as complete if it contain no reference to the question of the "foliation" in that region, as first raised in the year 1852 by the late Mr. D. Sharpe. In our paper which was laid before the Society at the last Meeting, we avoided entering upon this subject, reserving such remarks as we have to offer for a separate communication. At the same time we must specially refer to our preceding memoirs on the structure of the Highland crystalline stratified rocks, in which we have shown that the different mineral formations which succeed to each other offer distinct proofs of original deposit under water, some of them even containing organic remains. Our conviction of the truth of this view has been arrived at, not by any theoretical hypothesis, but by repeated and long-continued observations of the succession and nature of the stratified Highland rocks; and hence we are under the necessity of recording our dissent from the opinions of a distinguished geologist now no more, who, in a memoir published in the 'Philosophical Transactions,' and illustrated by a map and sections, has endeavoured to prove that the very lines which we refer to deposit are lines of a foliation which is the ultimate stage of the action of cleavage. We, on the contrary, referring to our former memoirs for our proofs of sedimentary deposit, will now point out that wherever cleavage does exist in these Highland rocks it is transverse to those laminæ which have been referred to foliation by Mr. Sharpe, and which we consider to be simply crystallized stratification.

In the early days of Scottish geology, it was shown by the illustrious Hutton and his contemporaries, that the gneiss and schists of the Highlands were truly sedimentary formations, and that their present crystalline structure arose from the action of heat at a period posterior to their deposition. Subsequently the same views were entertained and promulgated on all occasions by Macculloch, during and after his numerous explorations of the Highlands. Those eminent geologists and their successors, during many years, never doubted that the planes or laminæ of the schistose rocks represented former lines of stratification, and they wrote of the dip and "stretch" or strike of these altered rocks precisely as they would have done had they been treating of unaltered sandstones, shales, and limestones. But, after the publication, in 1846, of Mr. Darwin's observations on the metamorphic rocks of South America, attention was drawn more pointedly to the structure and origin of this class of rocks. That distinguished naturalist believed that, in the regions of Chili and Tierra del Fuego, the planes along which the separation of the crystalline particles had proceeded did not coincide with the original planes of bedding, but with the planes of cleavage. He proposed to apply the term "foliation" to the laminar arrangement of gneiss and schist—a term to which, if used merely to express this arrangement, without reference to its origin, we have no objection. But Mr. Darwin considered that his observations bore out the general inference, that foliation and cleavage are parts of the same process,—"in cleavage, there being only an incipient separation of the constituent minerals; in foliation, a much more complete separation and crystallization*:" and he applied this theory to the elucidation of large tracts of South America.

Now, however this doctrine may be borne out in regions which we have not seen, we hold that it is utterly inapplicable to the

* Darwin, Geol. Obs. South America, pp. 156–165.

Highlands of Scotland, or to any mountain-tracts in Europe which we have explored. In fact, all our contemporaries, with whom or with whose works we are acquainted, have treated such laminæ as marking, on the whole, the lines of original stratification. Thus, in 1827, when one of us explored the Highlands with Professor Sedgwick, that distinguished man clearly pointed out, *in situ*, the absolute independence of such foliation and cleavage; and thenceforward, and after repeated surveys of the same region during successive years, we have, on various occasions *, expressed our entire dissent from the doctrine and opinions of the lamented Mr. Daniel Sharpe, recorded in a memoir entitled "On the Arrangement of the Foliation and Cleavage of the Rocks of the North of Scotland †." As early indeed as the year 1835, and consequently eleven years before Mr. Darwin wrote, and seventeen years before the publication of Mr. Sharpe, Professor Sedgwick, in his remarkable "Memoir on the Structure of large Mineral Masses," actually enunciated the distinctions on which we insist in this memoir. In speaking of those crystalline schists of parts of England and Wales, and of the Highlands of Scotland, which are "finely foliated," he goes on to say:—"In general, however, the *foliated* uneven layers of these older formations belong, I believe, to beds, and not to cleavage-planes; and the oldest and most crystalline rocks, designated by the general term of schists, have no true slaty cleavage in the sense in which I have used the term ‡."

Professor Sedgwick thus defines these distinctions:—"*Bed* is always applied as the English synonym of *stratum*; and the words *thick-bedded, thin-bedded, thick-flaggy, thin-flaggy*, and *laminated*, are words in common use, and express well enough different modifications of stratified structure. The term *foliated*, again, expresses very well the peculiar structure of mica-schist, and the fine, glossy, undulating layers of greywacke." After enumerating the essential difference between slaty and flaggy structure, he adds:—"In this way, *foliated* as distinct from *laminated*, and *slaty* as distinct from *flaggy*, become terms of a definite meaning §."

It should be further remembered, that in the year 1840, and also before Mr. Darwin's observations were published, the Local Director of the Geological Survey, Professor Ramsay, devoted himself specially to a careful survey of Arran, and in the early part of the following year published a descriptive account of the geology of that island. In speculating upon the origin of the quartz-layers that are interbedded in its schists, he remarks that these quartz-layers "lie in regular laminæ, very numerous, and *parallel to the plane of stratification*. Sometimes these alternations are almost as minute as the leaves of a closed volume." He thus clearly

* Report Brit. Assoc. Glasgow, 1855, Trans. of Sections, p. 86. Siluria, 2nd edit. pp. 179, 195. Quart. Journ. Geol. Soc. vol. vii. p. 168; and vol. xv. p. 391.

† See Philosophical Transactions, vol. cxlii. p. 445 (1852); with a coloured map of Scotland and sections.

‡ Trans. Geol. Soc., new series, vol. iii. p. 479.

§ *Ibid.* p. 480.

recognizes the existence of stratification-planes, and the parallelism of these as a whole with the interlaminations of quartz *.

The late Mr. Daniel Sharpe, in his memoir, endeavoured to prove that the foliation-laminæ of the gneiss were arranged in great arches, ranging in a N.E. and S.W. direction. But true slaty cleavage, as we have already remarked in our preceding memoir, is rarely met with in the Highlands, and where it does occur, it is nearly always more or less transverse to the planes of stratification. Again, whilst Mr. Sharpe does advert to rare examples of cleavage-planes traversing those laminæ which he refers to foliation (Phil. Trans. 1852, vol. cxlii. p. 449, and pl. 23, figs. 1, 3, 4), he maintains throughout his memoir, and illustrates the view in his general sections, that all those bands of different mineral matter which we have shown in preceding memoirs to be successive *deposits*, are due to *foliation* only. He altogether loses sight of the great intercalations of limestone, some of which, as we have formerly shown, contain organic remains. Let us now give some illustrations of our views.

At Dunkeld in Perthshire, at Easdale in Argyllshire, or at Ballyhulish, where true cleavage exists, it is seen to cut through those lines of colour, by which, in finely levigated clay-slates of a homogeneous composition, the original laminæ of deposit are recognized. In the argillaceous schists on the flanks of the Grampians, and notably near the Spittal of Glenshee, where the strata are often violently contorted, as seen in the specimen we now exhibit †, the cleavage-planes are rudely parallel to each other, and cut right across the undulating layers of black carbonaceous schist. This specimen is indeed a good example of the view now adopted, that the parallel planes of cleavage are due to lateral pressure; for here we have a proof that the original beds of carbonaceous shale have been so intensely squeezed up as to produce the contortions exhibited, whilst the cleavage-planes traverse them. We have also at hand in this locality the explanation of these contortions in the existence of numerous points or bosses of syenite, porphyry, and other similar rocks, which protrude to the surface around the Spittal of Glenshee. The compressed schist to which we allude is so highly carbonaceous in the little burn to the west of the inn at the Spittal,

* Professor Ramsay, in a paper read before the Geological Society (Quart. Journ. Geol. Soc. vol. ix. p. 172), discusses the metamorphism of Anglesea, and refers it to a period *anterior to that of the cleavage* of the Welsh slates. He adds, that " if the rocks be uncleaved when metamorphism takes place, the foliation-planes will be apt to coincide with those of bedding; but if intense cleavage has occurred, then we may expect that the planes of foliation will lie in the planes of cleavage." And in the letter-press explanation of Sheet 40 of the Horizontal Sections of the Geological Survey, he unhesitatingly declares his belief, that the metamorphic rocks of Anglesea are the prolongation of the green and purple grits and slaty rocks of Bangor; and that, moreover, they are disposed along an anticlinal axis, the S.E. side of which consists of the higher part of the Cambrian series, overlaid by the Lower Silurian, while the N.W. side brings down the same succession, though broken by a line of fault, " thus completing the series, and adding to the probability of the Cambrian age of most of the metamorphic rocks of Anglesea."

† This specimen is deposited in the Museum of Practical Geology.

that some of the points of rock blacken paper like a black-lead pencil, and we therefore supposed it might be graphite; but a chemical examination of it at the Government School of Mines by Mr. C. Tookey has shown that it is simply highly carbonaceous black schist, with some mica, the rock yielding on combustion nearly 16 per cent. of carbon.

In arriving at the belief which we entertain, that all the "foliation" of the crystalline rocks of the Highlands which we have examined is nothing more than the original laminæ of deposit under water, of sand, clay, lime, mica, &c., which have been so altered as often to segregate in one layer more mica, and more sand or clay in the others, thus evolving felspathic, quartzose, and micaceous crystalline laminæ, we are sustained in our inference by an appeal to the whole succession of the mineral deposits of the north of Scotland. For we have shown that these successive deposits are so knit together by transition and conformable superposition, that it is quite impossible to exclude from the series those of its members which still exhibit not only a mechanical origin, but also contain organic remains. From our old acquaintance with the late Mr. D. Sharpe, we are convinced, that if, instead of making one rapid survey only, in which, full of a new theory, he naturally applied it, with his well-known energy, he had year after year examined these Highland rocks, he would have seen the impossibility of excluding (as he did) the greater part of the quartz-rock of Scotland from the crystalline series, merely, as he says, because it is "an altered sandstone of which the mineral character has been changed by plutonic action." He would, we doubt not, on a more careful survey, have seen that this very rock and its associated limestones are integral and even lower parts of a large portion of that same crystalline series; and then he would have admitted, that, as these pure quartz-rocks (evidently nothing but altered sandstones, and in which Annelides and an Orthoceratite have been found) graduate into micaceous quartz-rocks, mica-schists, and gneissose rocks, they could not be divided geologically into two separate classes, but form truly one great series, varying in its mineralogical characters as well as in the extent and form of its metamorphism.

The views which we entertain have been indeed, to a great extent, sanctioned by the examination of the older rocks of the Highland border by a very close and accurate observer of structure. Distinctly objecting to the general application of the term *foliation*, Mr. Sorby has shown that one of the structures of metamorphic rocks "has every character that would be the result of stratification, even in some cases including the current structures *."

Again, the same author, in his notice of the microscopical nature of mica-schist, has demonstrated, that in one class of these rocks the flakes of mica lie in the plane of the alternating layers of different mineral composition, whilst in the other class the flakes of mica traverse the original lines of bedding like slaty cleavage. He therefore proposes the terms "stratification-foliation" and "cleavage-

* Report Brit. Assoc. Adv. of Science, 1855, Trans. of Sections, p. 96.

foliation." The latter structure is partially to be seen in the schistose rocks on the coast to the south of Aberdeen, which are highly metamorphosed, and have never been examined by us; but we have to thank Mr. Sorby for the pertinent induction respecting them, "that the peculiarities in the rocks having 'cleavage-foliation' cannot be explained except by supposing that they have been metamorphosed stratified rocks," adding "that the cleavage-foliation is the effect of previously existing cleavage, and not that slaty cleavage is a partially developed foliation*."

In dissenting from the views of Mr. Sharpe on this one essential point, we must add, that there are many passages in his memoir with which we entirely coincide. Thus, nothing is more true than his declaration, that the geographical separation between gneiss and mica-schist and chloritic schist throughout the north of Scotland, as laid down by Macculloch, has been drawn too arbitrarily. We fully admit, and have shown, that many of the strata so defined by that author have "the same geological relations." But when Mr. Sharpe applied to their internal divisions the term "foliation," and, separating it entirely from stratification, contended that such foliation is the ultimate term of the same action which produced slaty cleavage, we are completely at issue with him.

Whether we admit, with Phillips†, Sharpe‡, Sorby§, Tyndall‖, and others, that the parallel cleavage of rocks was produced by mechanical lateral pressure of the strata, or, following the original speculation of Sedgwick, conceive that it was the result of crystalline and polar forces, it is quite obvious throughout the Highlands of Scotland, that this action was not the same as the *modus operandi*, whatever it was, which changed the original layers of sand, mud, and lime into crystalline laminæ.

In short, as the one set of planes traverses the other, and as the straight lines of parallel slaty cleavage (wherever they occur) are strikingly distinguished from the convoluted and twisted layers of different colour and composition, we are at a loss to imagine how these two results could ever have been referred to different degrees of intensity of one and the same cause.

As we have already dilated on the true cleavage as affecting the slaty rocks of Islay, Easdale, and the adjacent tracts of Argyll and Ballyhulish, &c., it will be remembered that in rare instances only does this feature coincide with the layers of deposit, any more than in Wales and other slaty tracts. Even along the Highland border, where Mr. Sharpe says that the foliation of the mica-schist and the cleavage of the slate "are both vertical along lines *so closely corresponding* that they may be considered continuous," we found in the slate-quarries of Dunkeld that there was a clear and manifest

* Report Brit. Assoc. Adv. of Science, 1856, Trans. of Sections, p. 78.

† See Report Brit. Assoc. Adv. of Science, 1843, Trans. Sect. p. 60; and 1857, p. 386, &c.

‡ Quart. Journ. Geol. Soc. vol. iii. p. 74; vol. v. p. 111.

§ Edinb. New Phil. Journ. 1853, vol. lv. p. 137; Phil. Mag. 1856, xii. p. 127.

‖ Notices Royal Institution, June 6, 1856.

distinction between the planes of cleavage and the lines of deposit* as marked by the colour of the slates. But the parallelism of the mica-schist (a sandy quartzose micaceous rock) to the clay-slate which succeeds, and to which Mr. Sharpe applies his remarks, is indeed one of the phenomena on which we have been all along insisting,—viz. that these different mineral masses of the Highlands succeed to each other regularly, and are fairly linked together, so as to form one great series.

In truth, if the observer follows any one mineral stratified mass upon the strike of the beds, he will often find that what at one extremity of it was highly crystalline is at the other much more earthy and unaltered. Again, if he examines many of the quartzose, schistose, and calcareous masses, he cannot fail to observe the essential characters of ordinary stratified sediments, such as way-boards dividing different mineral substances, wavy surfaces, joints, and all the concomitant appearances, including occasional gritty and even pebbly layers.

In Mr. Sharpe's map† there is one dominant feature which agrees with our observations. He gives to the gneiss of the Lewis and the western coasts of Sutherland and Ross a true north-westerly and south-easterly strike, and thus exhibits it at right angles to the strike of nearly all the other crystalline rocks of the mainland. But, never having observed the true order of superposition of the different mineral masses in the north-west, which is the foundation of all our induction, he follows Macculloch and unites all these crystalline rocks in one gneissose and micaceous series, and treats all our lines of stratification (and as such they were viewed by Hutton and also by Macculloch) as lines of "foliation." In fact, these so-called lines of foliation, and the transverse sections of them which Mr. Sharpe exhibits, may serve in a broad sense to represent our lines of stratification. In his generalized and theoretical diagrams also, his arches correspond in a general way with the lines of anticlinal axes; with this difference, however, that he does not insert, as the complement of anticlines, lines of synclinal troughs‡, which, as we have shown in the previous memoir, do really exist. He has, moreover, omitted altogether the bands of limestone, which are of such importance in demonstrating the coincidence of stratification-planes and lines of foliation, and in working out the geological structure of the Scottish Highlands.

No better illustration, indeed, of our own views can be given than by referring to Mr. Sharpe's own sections. First let us take his general sections, figs. 1 and 2, which in a traverse of ninety miles across Scotland exhibit at least five great anticlinals, and all his lines of foliation would be our lines of deposit. Next, in fig. 3, the mica-schist of Ben Lomond (chloritic schist, by the by, in great part) is represented as a "foliated" rock dipping to the S.S.E., whilst we

* Mr. Sharpe's sections indeed prove this; for the lines of cleavage in his fig. 1 traverse the lines of foliation, which latter are, according to our views, indications of the layers of deposition.

† Phil. Trans. 1852, plate 24.

‡ Unless his "fan-shaped" foliation represents the synclinals.

affirm that it is most clearly a depositary rock, the lines of original bedding of which coincide with the lines of metamorphism, since, besides the alternation of variously coloured schistose layers, there is really an intercalated bed of white quartzose and rounded pebbles, thus clearly proving the whole to have been originally a mechanically formed deposit. And, again, this one section in itself demonstrates the utter disconnexion between such true stratification-planes and cleavage; for in advancing to the S.E. into the overlying deposit of clay-slate, its layers (*folia* of Sharpe) are found to be traversed by a real slaty cleavage of which there is not a trace in Ben Lomond.

In fig. 4, where the section crosses Loch Tay, and where the dark schists have no cleavage, Mr. Sharpe omits the great feature of the case, the presence of those regularly bedded limestones which dip under Ben Lawers: and, if he had taken time to examine the internal structure of the country further to the N.W., he would have found other limestones reappearing together with the inferior quartz-rock beyond Glen Lyon, in the Loch and Moor of Rannoch, thus forming the other side of a great trough.

His section across Glen Shee (fig. 5) is another indication of those undulations of the upper schistose strata which we have observed. In that tract we have already demonstrated that the contortions of the original strata of black carbonaceous schist are traversed by lines of parallel slaty cleavage*, thus showing even in a hand-specimen the complete independence of cleavage from those lines in the crystalline rocks which are true lines of bedding and are wholly unconnected with slaty cleavage.

When Mr. Sharpe affirms that the contortions of gneiss and mica-schist "are far more complex than are ever found in the most disturbed strata, and are such as could only be produced in matter in at least a state of semi-fluidity," we refer the reader to the intensely curved Carboniferous strata in Bride Bay, Devonshire, or to the numberless contortions of the Devonian rocks of the Rhine. In the Silurian schists of the Lammermuir Hills, and numberless "grauwacke" rocks in other tracts, both abroad and at home, multitudes of similar rapid foliations have also been effected after the strata had been accumulated, and probably before they underwent that change by which they have passed into a highly crystalline state.

Again, in tracing the folds of the different mineral masses through the north of Scotland and in laying them down on maps, we have convinced ourselves that the strata so reappear on various parallels and so exhibit repetitions of the same geological relations to each other, *i. e.* the quartz-rock and limestone occupying one zone, and the mica-schists, the *quasi*-gneiss, and clay-slates another, that the effort made by Mr. Sharpe to unite them in one crystalline mass, which had been thrown into arches through the process of "foliation," is, we conceive, antagonistic to the true principles of geological inductive reasoning.

Looking at these different mineral masses, whether as they succeed to each other, or as they often gradually change their lithological

* Indicated also in Mr. Sharpe's fig. 5.

character in their lateral extension, as well as in their succession from quartz-rocks into mica-slates and *vice versâ*, and seeing that in some of their members they contain Silurian fossils, we have naturally come to the conclusion, that on the whole the crystalline stratified rocks of the Highlands are simply the metamorphosed equivalents of the Silurian grauwacke of the Southern Scottish counties, in which there is quite a large enough area of varied mineral matter to account for the greater part of such stratified crystalline rocks, particularly when we reflect on the enormous masses of granite, porphyry, and syenite which prevail in the North.

In conclusion, we express our belief that the so-called "foliation" of the Highland rocks is, on the whole, nothing more than such an alteration of the original deposits as caused the siliceous, felspathic, and micaceous ingredients to form separate layers, as seen in some instances, though in others they are intermixed in the same layer, and in some parts are simply altered sandstones and limestones with organic remains. In certain cases, like those pointed out by Mr. Sorby, there may doubtless be cleavage-foliations in the mica-schist, but these are clearly exceptions to the general rule.

Although we cannot here enter upon the great problem of how such changes in the character of the strata have been brought about, yet, looking to those researches in this line which have already been made (by M. Bischoff, M. Daubrée, M. Delesse, M. Deville, Mr. Sterry Hunt, and others), we confidently anticipate that the experiments of the chemical geologist will ere long solve the mystery, and in doing so we trust that they will confirm the conclusions at which we have arrived by a survey of the phenomena in the field.

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——. Notice sur les calcaires plutonisés de la péninsule de Sorrento. 1859. *From Sir R. I. Murchison, V.P.G.S.*

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Wallich, G. C. Notes on the presence of Animal Life at vast depths in the Sea, with observations on the nature of the sea-bed, as bearing upon Submarine Telegraphy. 1860.

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

February 15, 1861.

Annual General Meeting.

[For the Reports of the Council and Anniversary Address, see the beginning of this Volume.]

February 20, 1861.

J. Frederick Davis, Esq., Walker Iron-works, Newcastle-upon-Tyne; John Frederick Collingwood, Esq., 13 Old Jewry Chambers; Joseph Milligan, Esq., F.L.S., Hobart Town; Henry Porter, M.D., Fellow of Queen's College, Birmingham, Peterborough; and Richard Charles Oldfield, Esq., Bengal Civil Service, Farley Hill, Reading, were elected Fellows.

The following communications were read:—

1. *On the* Coincidence *between the* Stratification *and* Foliation *of the* Altered Rocks *of the* Scottish Highlands. By Sir Roderick I. Murchison, V.P.G.S., F.R.S., &c., and A. Geikie, F.G.S., F.R.S.E., &c.

[See above, page 232.]

2. *On the* Rocks *of* Portions *of the* Highlands *of* Scotland South *of the* Caledonian Canal; *and on their* Equivalents *in the* North *of* Ireland. By R. Harkness, F.R.S., F.G.S., Professor of Geology in Queen's College, Cork.

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§ 6. Sections from the south side of Ben-y-Gloe Mountains and Strath Ardle.
§ 7. Sections N.W. of the great zone of quartz-rocks and limestones. Section from Glen Lyon to Loch Treig.
§ 8. Section from King's House through Glencoe to Ballahulish.
§ 9. Section across the peninsula of Ardsheal from Benivair.
§ 10. Metamorphic rocks of the County of Donegal, and section of the east side of Lough Foyle.

§ 1. *Introduction.*—The recent labours of Sir Roderick Murchison in the N.W. Highlands of Scotland have so greatly increased our knowledge of this portion of Great Britain, as to place the age and arrangement of the rocks in this country in an entirely new aspect. The result of these investigations has been made known so lately * that it must be visibly impressed on the mind of every geologist, and consequently will require no special reference to be made thereto. In the memoirs in which these labours have been detailed, there is a "hypothetical view" expressed concerning the mass of metamorphic rocks which constitute the great bulk of the Scottish Highlands; and in this hypothetical view these rocks are looked upon as the equivalents of the "upper gneiss" found reposing upon the quartz-rocks and limestones of Assynt and Durness, and which occupies so large a portion of the north of Scotland.

Having had an opportunity of examining the deposits of Sutherland so amply described by Sir Roderick Murchison, and corroborating the results of his labours in the N.W. Highlands, I have felt myself in a position which has enabled me to extend to a more southern parallel investigations concerning the great area of Scottish metamorphic rocks, and, as will be seen in the sequel, from observations made last summer in many parts of the Highlands, and also in the north of Ireland, have arrived at the same conclusions as are expressed in the hypothetical views already referred to.

Before proceeding to detail the results of these observations, it is necessary to say something concerning the nature of the rocky masses which abound in the more southern part of the Highlands, more especially as these are laid down in the geological maps of this district. Certain rocks, to which the term metamorphic is usually applied, have had assigned to them somewhat definite areas

* See Quart. Journ. Geol. Soc., vol. xvii. p. 232 &c., as well as other previously published memoirs.

in the Highlands; and these rocks, generally designated gneiss, mica-slate, chlorite-slate, and clay-slate, have been looked upon as possessing a distinct arrangement as to superposition to each other. From what I have seen in the several areas which have been under my examination, it appears to me that these rocks, with names expressing lithological nature, have no definite relation as concerns geological position, although in some small areas this seems to be the case. Looking at these metamorphic rocks with reference to general results, I have arrived at the conclusion that, in whatever mineral condition they present themselves, this mineral condition is a purely local character, and that, in the same geological zone, in one spot we have clay-slate, in another chlorite-slate, in a third mica-slate, and in a fourth gneiss. These several rocks are altered deposits of varying shales and sandstones which were deposited during the same period in different portions of the older Silurian seas. These metamorphic rocks, to which I apply the general term "gneissose," although the word is in many instances a bad one, are spread over too great an extent in the geological maps of Scotland; and they are frequently represented as occupying large areas, over which granite or some other form of plutonic rock really prevails. And, although rocks of the latter nature seem to be so amply developed in the Highlands, great injustice is in many instances done to rocks of this description in the geological maps of Scotland.

With reference to the mode of arrangement of the other strata which are associated with the gneissose rocks (viz. the quartz-rocks and limestones), it has generally been assumed that these latter occupy a higher position than the former. This inference I have reason to conclude is not the result of observation, but has originated from the Wernerian theory and classification of rocks,—the more crystalline gneissose rocks having been looked upon as *primitive*, while the less crystalline and more distinctly stratified quartz-rocks and limestones were regarded as *transition*. This idea appears to have prevailed in the mind of Macculloch; and this order, in the arrangement of the stratified masses of the Highlands propounded by him, has been to a great extent adopted by geologists without inquiring into the basis on which it rests.

The principles which actuated Macculloch in his classification of the Highland rocks may be ascertained by referring to his memoir "on Quartz-rock," where, after quoting Playfair with reference to the structure of Schihallien, he goes on to say, "If this ridge is connected by any system of alternation with the sandstone of Glen Lyon, mica-slate will appear to be a rock formed posteriorly to, or alternately with, a rock of recomposed structure. Thus a *primitive* will be found to alternate with a *transition* one,—an anomaly which either renders this distinction as useless as it is artificial, or compels us to modify the definition of transition rocks or to form that total change of arrangement which I have more than once suggested with regard to primitive and transition classes*."

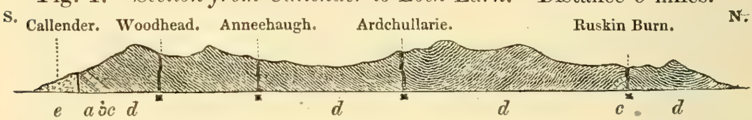
* Geol. Trans., vol. ii. p. 470.

Again, in the same memoir, with reference to Jura, alluding to the gneissose rocks, he states that these are "apparently superimposed on the quartz-rock*;" and yet, after using the word apparently as though this was not the true position, he goes on (at p. 456) to quote Prof. Jamieson, who says that "quartz-rock rises at an angle of 45° from under micaceous schists."

The same idea as to primitive and transition seems to have been the leading feature in his mind with relation to arrangement when he visited Glen Tilt; and yet, when he comes to describe definitely the sequence of rocks here, we generally find that his statements are hostile to his preconceived ideas.

These general observations will serve as a prelude to what I have to add to the geology of portions of the Highlands lying south of the Caledonian Canal; and, as these observations have reference to purely physical geology, I shall proceed to describe the several sections, and afterwards the general results obtained therefrom.

Fig. 1.—*Section from Callender to Loch Earn.* Distance 9 miles.



e. Old Red Sandstone. *d.* Gneiss. *c.* Limestone. *b.* Shale.
a. Quartz-rock. * Trap-rocks.

§ 2. *Section from Callender to Loch Earn* (fig. 1).—In the immediate neighbourhood of Callender, deposits belonging to the Old Red Sandstone series are extensively developed. At the distance of about a mile and a half to the N.W. of the village, the great line of fracture separating the rocks of this age from the metamorphic strata of the Grampians is seen. In Leny Glen the point of contact between the rocks appertaining to these different series is exhibited, the rocks of the Old Red series appearing in the form of conglomerates; immediately on the N.W. of them, above the line of fault, quartz-rocks, referable to the older deposits, occur; and upon the small development of the quartz-rocks here seen, black shales are found reposing conformably. These quartz-rocks and black shales dip towards the N.N.W. On leaving this glen and continuing the section on its rise, we have, at Leny lime-quarry, the same black shales manifested, dipping N.N.W. at 35°, and possessing an anthracitic aspect, which allies them in lithological nature with the anthracitic shales of the Lower Silurians of the South of Scotland. In these black shales, which from their nature might have afforded abundance of Graptolites, no fossils were obtained. Resting conformably on these shales, a thin layer of limestone is seen, of a dark grey colour, regularly bedded, but contorted, and abounding in white veins of carbonate of lime. This limestone, which also afforded no fossils, and which has a thickness of about eight feet, is succeeded by grey clay-slate, in some instances wea-

* Geol. Trans., vol. ii. p. 454.

thering to a purple colour, and with gneissose layers intercalated in it. This latter mass is conformable to the limestone; and, passing upwards into regular mica-slate, it forms the hills which lie N.W. of Leny lime-quarry. On the road from Callender to Loch Lubnaig, at Woodend, about half a mile from Kilmahog toll-bar, quartz-rocks, similar to those of Leny Glen and having the same inclinations, appear. The succeeding black shales and limestones are not seen, being masked by débris, but the overlying purple shales occur, passing into gneissose rocks; and these are intersected by a trap-dyke, termed locally "*Blue Whin*," at Woodhead Quarry.

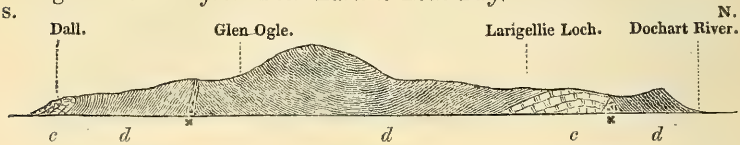
The arrangement of the rocks forming a portion of the southern boundary of the metamorphic masses of the Highlands, as seen in the neighbourhood of Callender, is exhibited in fig. 1, and is as follows:—First and lowest, quartz-rock, a small portion only of which is exhibited; second, black shales; third, thin grey limestones; and fourth, clay-slates (shales) passing into gneissose rocks.

Beyond the Woodhead whin-quarry we have a considerable development of that form of metamorphic rock to which the name chloritic schist has been applied, but of which the term "chloritic gneiss of a fine grain" more fully expresses its nature; and this rock continues with the same N.W. dip to Anneehaugh, about three miles from Callender, where it is intersected by another trap-dyke containing red nodules. North of this dyke the same chloritic gneiss is seen dipping in the same direction, but at angles varying from 40° and upwards, until we reach Ardchullarie, where another trap-dyke makes its appearance; and to this the name "Black Whin" is applied. These trap-dykes produce very little effect on the dip of the metamorphic rocks. After leaving Ardchullarie, we find that northward the strata become much disturbed, and show a disposition to assume S.E. dips. At Creggan, about half a mile north of Strathire village, this S.E. dip is very apparent. At Ruskin Burn another trap-dyke occurs, and also a vein-like mass of limestone very thinly overlain by gneiss, the latter dipping N.E. There is a considerable amount of disturbance in the strata here, and northwards this disturbance also prevails. This mass of gneissose rocks occurring in the area between the hills of Leny and Loch Earn, and which possesses a great thickness, overlies the limestones of the southern margin of the Grampians; and, notwithstanding its flexures and contortions, clearly arranges itself as a synclinal axis in the neighbourhood of Strathire village, from underneath which we have limestones making their appearance at Leny on the S.S.E., and at Ruskin Burn on the N.N.W. The mode of arrangement of the rocks in this interval is shown in fig. 1.

§ 3. *Section from Loch Earn to Loch Tay* (fig. 2).—At the N.W. end of Loch Earn, at Dall, a considerable mass of limestone, having somewhat of a gneissose aspect, and exhibiting itself in great thickness, is seen. This limestone at this locality is nearly horizontal; but at the east side of the quarry, where it has been wrought, it inclines at a low angle towards the E.S.E., and is succeeded by chloritic gneiss. Near the seventh milestone from Killin, at Loch

Earn head, this same gneiss also makes its appearance, dipping in the same direction at an angle of 20°; and at the bridge, about a mile north of Loch Earn head, a hard trap occurs, from which the

Fig. 2.—*Section from Loch Earn to Loch Tay.* Distance 6 miles.



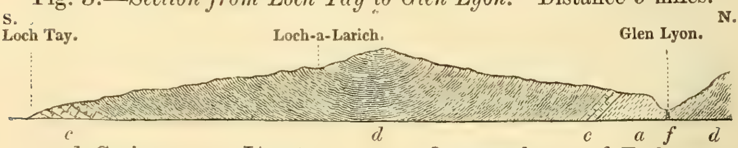
d. Gneiss. *c.* Limestone. * Trap-rocks.

metamorphic strata seem to derive the E.S.E. inclination. On the north side of this mass of trap, which is much intersected by quartz-veins, a reversed dip is seen and N.W. inclinations obtain.

Along Glen Ogle, the gneiss, which is micaceous, is only slightly inclined, and has quartz-veins running along the lines of stratification. At Larigellie Loch, a small lake near the water-shed of Glen Ogle, the E.S.E. dips become most prevalent; and these continue to the shepherd's cottage, where limestone again occurs, dipping at an angle of about 40° E.S.E. This limestone is seen along the course of the Larigellie Burn, where it becomes flattened; and at the bridge, where the high road crosses this stream, about a mile and a half from Killin, another mass of trap makes its appearance. In the arrangement of the strata in the section between Loch Earn and Loch Tay, we have a mass of limestone near Loch Earn which underlies the gneissose rocks, and near Loch Tay gneissose rocks are seen, superimposed also in limestone. This limestone, as seen in the Larigellie Burn, seems to form a rounded anticlinal; for, immediately on its north side, we have gneissose rocks amply developed in the River Dochart, and these dip N.W. at an angle of 20°.

§ 4. *Sections from Loch Tay to Glen Lyon* (fig. 3).—The rocks just referred to, as seen in the Dochart, also appear on the road from

Fig. 3.—*Section from Loch Tay to Glen Lyon.* Distance 9 miles.



d. Gneiss. *c.* Limestone. *a.* Quartz-rock. *f.* Fault.

Killin to Lochie Bridge, and for a short distance along the road to the eastward, having the same N.W. inclination. About half a mile east of Lochie Bridge strata of limestone occur, having thin bands of rotten gneiss interstratified; the limestone is also thin-bedded. These limestones dip N.N.W. at 60°. At Mornish, about two miles east from Killin, similar limestones also occur. They have, however, a gneissose aspect, and are greatly contorted; but still the prevailing dip (N.N.W.) of this portion of the Loch Tay rocks obtains. To the south of these contorted limestones at Mornish, a flaggy trap is seen. These limestones of the north side of Loch Tay are well exhibited for a considerable distance along their strike, on the road leading from Killin to Kenmore. They are well seen on their dip in traversing the mountain-road from Loch Tay to Inverwick in Glen Lyon; and also in the streams which run nearly parallel to this mountain-road, which intersect the valleys lying between Ben Lawers on the east, and Meal Girdy on the west. The section which is shown in this traverse between Loch Tay and Glen Lyon, is probably one of the most instructive which can be seen in any part of the Grampians south of the Caledonian Canal. Commencing near the north margin of Loch Tay, we have the thin-bedded limestones with their N.N.W. dips succeeded conformably by gneiss; but this gneiss becomes much contorted in the neighbourhood of Loch-a-Larich; still the prevailing N.N.W. dip is seen. After passing the water-shed, a reversed dip in this gneiss occurs; and these reversed S.S.E. dips are well seen in the rocky course of the brook which has its origin on the N.E. side of Meal Girdy. These gneissose rocks, which are seen in almost constant succession for more than two miles and a half along this stream, have a S.S.E. dip, which averages 45°. Then, as we approach Glen Lyon, we find coming out conformably beneath the gneiss limestones like those of the north side of Loch Tay; and after passing downwards through the limestones, we find underneath them, and also conformable to them, the thick masses of quartz-rocks which are so extensively developed along the south side of Glen Lyon. After crossing this area in a northern direction to Inverwick, we find the quartz-rocks suddenly disappear, and on their N.W. side we have thin-bedded blackish gneissose rocks with the same S.S.E. dips; and rocks of this character are well seen in the course of the burn leading from Inverwick to Dall, on the south shores of Loch Rannoch. Reference will subsequently be made to this gneiss when describing the sections which lie N.W. of the zone marked in Sir Roderick Murchison's sketch-map* of the geology of the north of Scotland, as occupied by "quartz-rock and limestones."

§ 5. *Section from Dunkeld to Blair Athol* (fig. 4).—In portions of the Grampians which lie N.E. of the areas already referred to, we have sections which are very nearly allied to those already described. In many instances, in these north-eastern areas, the rocks are by no means so well exposed as in the districts which have been under previous notice. In the neighbourhood of Dunkeld the relations of the Old Red Sandstone deposits to the metamorphic rocks of the Grampians are well seen,—the former being cut off from the latter by masses of trap, and the metamorphic strata marked by the N.W. dips which distinguish the southern margins of this class of rocks. With reference to lithological character, we have at Dunkeld schistose beds, possessing the nature of clay-slates, as the lowest exposed rocks of the metamorphic series; and these

* Quart. Journ. Geol. Soc., vol. xv. pl. 12.

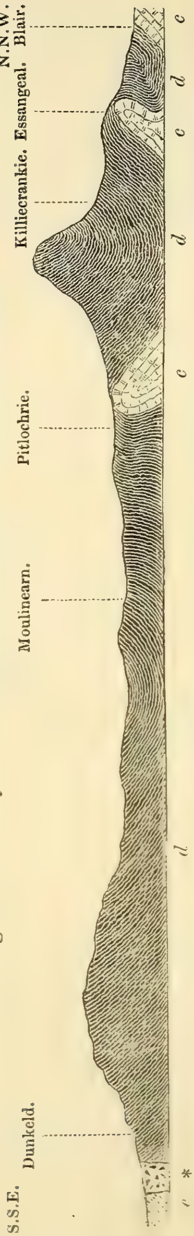


Fig. 4.—*Section from Dunkeld to Blair Athol.* Distance 20 miles.

e. Old Red Sandstone. *d.* Gneiss. *c.* Limestone. * Trap-rock.

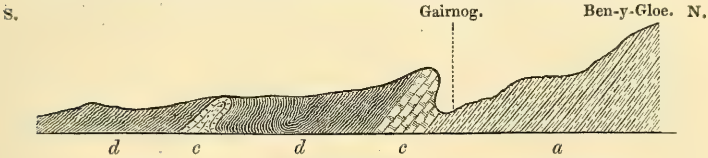
are succeeded by micaceous schists passing upwards into gneiss. This must, as already mentioned, be regarded only as a local circumstance. After leaving Dunkeld for the N.W., the valley of the Tay becomes so expanded that the exhibitions of rocks are by no means frequent. On approaching Moulinearn we find indications of a reversed dip prevailing among the gneissose strata; but on reaching Pitlochrie at the bridge over the Tummel, a N.N.W. dip obtains; and near this we have limestones very abundantly developed, inclining at an angle of 35°. The Pitlochrie limestone has a somewhat gneissose appearance, and is to a considerable extent made up of layers of a grey and a white colour, the latter resulting from the deposition of more crystalline carbonate of lime in the hollows produced by the opening of the laminæ consequent on flexures and contortions.

This limestone at Pitlochrie in its nature has great affinity to that on the north side of Loch Tay; and there is, from its line of strike, strong reason to regard it as an extension north-eastward of the Loch Tay beds.

At Craigeoch, about a mile N.W. from Pitlochrie, we have gneissose rocks coming on; and these, dipping at 70° N.N.W., represent the rocks of the same character which have been described as succeeding the limestones of Loch Tay in the section from this loch to Glen Lyon. Continuing the section northwestwards, we have, in the neighbourhood of the Pass of Killiecrankie, reversed or S.E. inclinations among the gneissose rocks; and at Essangeal a thick grey limestone, with imperfect bedding, and seeming to dip under the gneissose strata, appears. Between Essangeal and Blair no rocks are exhibited on the road; but at the latter spot we have the limestone again shown with a S.E. dip. This limestone of Blair I regard as the same as that seen at Essangeal, and that its appearance here is the result of one of those contortions, exceedingly common in the rocks of more eastern parts of the Highlands, which have originated from the influence of those great masses of plutonic rocks so abundant in these portions of the Grampians.

§ 6. *Sections from the South Side of Ben-y-Gloe Mountains and Strath Ardle* (fig. 5).—On leaving Blair and passing in the direction of the southern flanks of the Ben-y-Gloe Mountains, a moory area is

Fig. 5.—*Section from Ben-y-Gloe Southward.* Distance 3 miles.



d. Gneiss. *c.* Limestone. *a.* Quartz-rock.

traversed, which affords at irregular intervals exposures of dark-coloured gneiss, dipping S.E., or from the Ben-y-Gloe range. This gneiss is well seen in the course of the Gairnog stream, which enters the Gary near Killiecrankie. At the shepherd's house near this stream, on the road over the hills from Blair into Strath Ardle, these gneissose rocks dip S.E. at 45°, and are seen overlying limestone. To the north of this parallel of limestone, black gneiss again occurs, having the same inclination, and is found reposing on limestones which are well seen in the escarpments which lie between the small Loch Vallean on the south and the Ben-y-Gloe Mountains on the north. The relations which these limestones bear to the quartz-rocks of the Ben-y-Gloe Mountains are not seen, as the sides of the latter mountains afford only débris of quartz-rocks, and along the stream-courses which drain their south flanks, no exposures of rock *in situ* are visible. It is probable that the connexion between the limestones and the quartz-rocks of Ben-y-Gloe is cut off by plutonic masses ; for we find the water-shed which separates the Gairnog from Alt-Clunie, a stream flowing into Strath Ardle, to be composed of coarse-grained syenite ; and rocks of a plutonic character are extensively developed along the southern margins of the great mass of quartz-rocks which occur in this portion of the Highlands, although no indications of such rocks are laid down in any geological map of this portion of Scotland. From Alt-Clunie, below the syenitic area, gneissose rocks occur, inclined at a very high angle towards S.S.E. These soon become perpendicular, and then dip N.W. On the west they form the great mass of Ben Bhrackie ; and from their southern slopes we have, at Clunie, the limestone band of Pitlochrie again making its appearance.

This parallel of limestone, which has a N.W. dip, and which I regard as a continuation of that seen on the north side of Loch Tay, extends itself still further eastwards ; it has been worked at the Market Muir, about half a mile N. of the village of Kirkmichael. It is now wrought two miles E. of Kirkmichael, at Dunien, where it is well seen, dipping N.N.W. at 35°, and is of a uniform light-grey colour, with very distinct bedding and laminæ, and possessing lithological features which very nearly ally it to some of the carboniferous limestones. No traces of fossils, however, occur in it. At Dunien, on its south side, trap appears. From Dunien eastwards its course is well seen. It has been quarried at Balchraggan and Soilairzie (at the latter place it has white lenticular bands of pure carbonate of lime along the laminæ); and from hence it extends across Glen Shee by Mount Blair into Glen Isla.

With reference to Glen Shee, the valley being open and the country on the hill-sides to a great extent clothed with heath, the sections are not so satisfactory as in many other portions of the Highlands. A dark-grey limestone was, however, formerly worked at Balanzien, about two miles S. of the Spittal. The exposure here is only imperfect, and the limestone apparently dips N. (?) On the hill on the north side, a fine-grained grey syenite is seen. From the Spittal, up Glen Beg, on the north side, great masses of red porphyry manifest themselves; but the same grey limestone of Balanzien becomes again visible in the higher part of Glen Beg; and, from the verdant herbage on the S. side of the stream, this limestone would appear well developed in this valley. At the spot on the road-side where it has been wrought, its arrangement is irregular and its dip indistinct. In the hill above this quarry on the N., contorted gneiss is seen with a N. inclination. From the section here no definite conclusions can be arrived at concerning the relative arrangement of the gneissose limestones and quartz-rocks. The influence of the plutonic area, which commences on the S.W. of the Ben-y-Gloe Mountains, and, extending eastward, unites with the great granitic areas of Aberdeenshire, has so far broken up the several metamorphic rocks as to render their arrangement almost unintelligible in the regions which lie immediately south of this plutonic area. With reference to Glen Tilt, Macculloch alludes to the confused arrangement which prevails in this valley among the strata. There are, however, certain statements occurring in his memoir (Geol. Trans. vol. iii.) which lead to the inference that on the south side of the Tilt the *limestones* "invariably" dip to the south at varying angles (p. 305); and as regards the quartz-rocks of Ben-y-Gloe, Macculloch remarks that these are seen alternating with limestones, which are again succeeded by the mica-slate (p. 307). The following statement also occurs:—"We have seen that the great mass of quartz-rock is followed by a small bed of limestone, and that this again is succeeded by micaceous and clay-slate, terminating the series of the bedded rocks in this direction" (alluding to the south) (p. 312).

From the sections which have already been described, and from the observations of Macculloch, it is evident that the sequence of rocks from the margin of the quartz-rock area towards the southern limits of the Grampians is as follows:—First and lowest, quartz-rocks; secondly, grey limestones, in some instances with lenticular bands of white carbonate of lime. These limestones are of very varying thickness, and in some instances appear to thin out altogether; and are succeeded by, thirdly, the gneissose rocks, which occupy so great an area in the Highlands of Scotland.

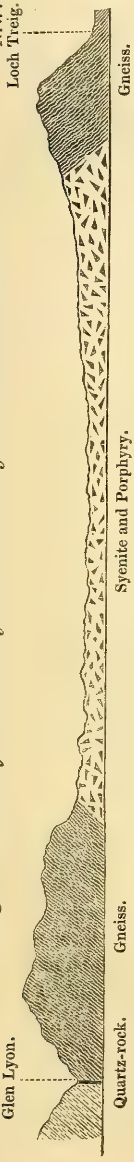


Fig. 6.—*Section from Glen Lyon to Loch Treig.* Distance 20 miles.

§ 7. *Sections N.W. of the Great Zone of Quartz-rocks and Limestones. Section from Glen Lyon to Loch Treig* (fig. 6).—Allusion has already been made to the black gneiss which is seen having a S.E. dip in the north side of the quartz-rock zone at Inverwick. In Glen Lyon, rocks of this nature, and with only slight modifications in their dip, extend themselves to the western end of Loch Rannoch, where an extensively developed area of syenite occurs; and from this syenite the gneissose rocks usually incline south-eastward in the neighbourhood of this lake.

The area occupied by this syenite, as shown in geological maps, fails to afford anything like an adequate idea concerning the extent of country which this rock covers. From the head of Loch Rannoch it extends along the mountain-road leading to Fort William—at least as far as Loch Ouchan, and from this, westward, almost to Loch Treig; but its area was not definitely determined. In the form of a flesh-coloured porphyry, this plutonic rock occurs in all the streams which drain the hills lying N. and S. of Oise-dhu, and the lakes through which this stream flows in its course to the Leven. This great plutonic area, coloured as gneiss in geological maps, seems to abut against the trap-rocks of Glen Coe.

At the head of Loch Treig we find it flanked by gneiss, which dips N.W., or from its S. margin, as at Loch Rannoch; the same rock inclines S.E. from its southern boundary.

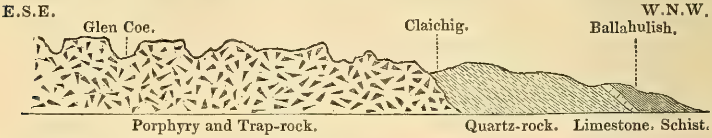
§ 8. *Section from King's House, through Glen Coe, to Ballahulish* (fig. 7).—The plutonic rocks just referred to extend to King's House; but on passing westwards towards Glen Coe, the dark porphyries and trap-rocks which exclusively fill this gorge, soon make their appearance. They occupy the whole of the glen to Claichig, where we have stratified rocks coming abruptly against the traps, as seen on the hill-slope immediately opposite the small inn at Claichig.

These stratified rocks dip W.N.W. at 45°, and they have somewhat of a gneissose aspect, but are much more highly siliceous than ordinary gneiss. Macculloch alludes to their differing from mica-slate, and designates them schistose "quartz-rocks*."

* Geol. Trans. vol. ii. p. 475.

They vary altogether from the rocks which occur to the west of them; and from their nature and position I look upon them as the representatives of the true quartz-rocks. At Ballahulish they are

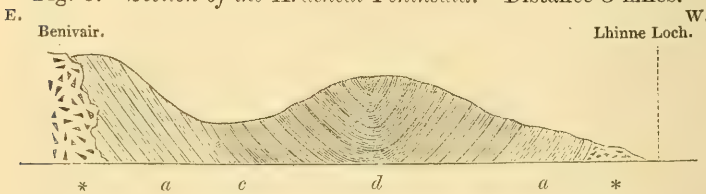
Fig. 7.—*Section from Glen Coe to Ballahulish.* Distance 8 miles.



succeeded by the dark-grey limestone, above which occurs the slate of this locality, having the same direction of inclination—viz. W.N.W.

§ 9. *Section across the Peninsula of Ardsheal from Benivair* (fig. 8).—Immediately E. of the inn at Ballahulish syenite again makes its appearance, and this mass of syenite extends S.W. along the coast to near Ardsheal, where it becomes flanked on the coast by meta-

Fig. 8.—*Section of the Ardsheal Peninsula.* Distance 3 miles.



d. Schist. *c.* Limestone. *a.* Quartz-rock. * Syenite and trap-rocks.

morphic rocks, in the form of quartz-rocks and limestone. On the east of the Ardsheal peninsula the syenite is seen forming the hill of Benivair, against which, on the west, there occurs a mass of quartz-rocks, which, when in proximity to the syenite, contains crystals of felspar, and becomes almost a porphyry. This quartz-rock, more remote from the syenite, is much intersected by joints, and has the stratification very indistinct; but the laminæ incline at a very high angle, N.W. This quartz-rock at Ardsheal is worked for ceramic purposes, and is know nunder the name of "*china-rock.*" On its N.W. side it becomes more distinct in its stratification, and is succeeded by a grey limestone, about twelve feet in thickness. Above this limestone the dark-grey slates are seen dipping in the same direction; but on passing over the Ardsheal peninsula, the inclination of these slates becomes reversed. On the western side the quartz-rocks again make their appearance, dipping under the slates; and these quartz-rocks repose against another mass of syenite, which forms the extreme west of the Ardsheal peninsula. In the west portion of this section no limestone is seen; and this may either result from the thinning out of the narrow limestone-band, or the limestone may exist, but not be visible, from the covering up of the junctions by soil.

The south-east side of the Ardsheal section exhibits the arrangement of the rocks seen between this locality and Appin. At Port Appin thick masses of quartz-rocks are seen, which are greatly contorted, having a prevailing S.E. dip. These are succeeded conformably by dark slates; and the arrangement here represents the N.W. end of the Ardsheal section.

The limestone islands which occur in Loch Linnhe exhibit calcareous strata in great development. In Sheep's Island these limestones are much contorted, and very nearly perpendicular, but with a predominant S.E. dip. Judging from this, we might be induced to infer that the strata here pass under the quartz-rocks of Port Appin; and if this be the case, they represent a zone of calcareous rocks altogether different from that previously alluded to, and, under such circumstances, they must be regarded as the equivalents of the thick limestones of Assynt. But perhaps it may be premature to arrive at this conclusion without more evidence than that at present afforded by the sections on this coast.

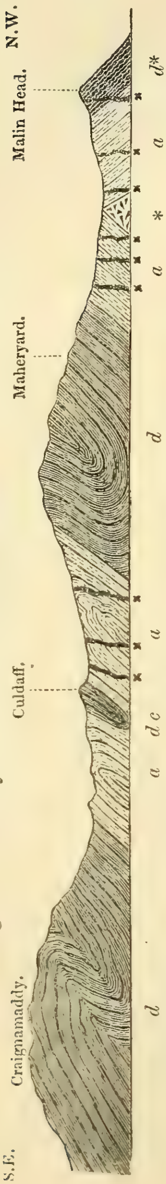
The sections which the districts lying N.W. of the area of quartz-rocks and limestones already referred to exhibit show, with probably the exception of the islands in Loch Linnhe, a sequence of stratified deposits very nearly allied to that which the region S. of this zone manifests. Quartz-rocks at the base, succeeded conformably by limestones, and these by gneissose or dark slaty rocks, make up the stratified beds N.W. of the zone of "quartz-rocks and limestones" which extend from Jura to the N.E. coast of Scotland. The rocks in the areas separated by this zone represent each other in arrangement and almost in mineral nature,—the only difference being in the character of the highest member, which occurs as a blackish slate on the west coast, while towards the south-east its equivalent has a gneissose aspect. This conclusion, as to similarity in age and position among the deposits south of the Caledonian Canal, supposes the existence of a great line of fault traversing the Grampians in a S.W. and N.E. direction; and this line of fault—parallel to the great S.W. and N.E. fault along the southern margin of this range of mountains separating the metamorphic rocks on the N.W. from the Old Red Sandstone series on the S.E., extending from sea to sea—is well seen in Glen Lyon along the northern edge of the quartz-rocks. On the N. of this line of fault we have a great downthrow, the higher beds of the series (the gneissose rocks) being again repeated; and as we approach the N.W. coast of Argyllshire, we have the lower members (the limestones and quartz-rock) again brought to the surface by the agency of plutonic masses.

With reference to the relations which these quartz-rocks, limestones, and gneissose strata, constituting so much of the great mass of the Grampians, bear to other rocks of a similar nature in the N.W. and N. of Scotland, I cannot better illustrate this than by referring to Sir Roderick Murchison's "Section across Lochs Eriboll and Hope*." In this section the upper quartz-rocks, upper limestone, micaceous and quartzose flagstones, and micaceous and gneissose flagstones represent the series of strata which form the Grampians S.

* Quart. Journ. Geol. Soc., vol. xvi. p. 226.

of the Caledonian Canal, as exhibited in the sections; and the results of my observations have induced me to conclude that on the mainland the lower rocks of this section are not represented, and that we have no metamorphic rock, either in *nature* or *arrangement*, in this great area of Scotland, that can be paralleled with the "fundamental gneiss" of Sutherland and Ross.

Fig. 9.—*Section from Malin Head to Inishowen.* Distance 20 miles.



d. Chlorite-schist. *d**. Gneiss. *c.* Limestone. *a.* Quartz-rock. * Syenite and Trap-dykes.

§ 10. *The Arrangement of the Metamorphic Rocks of the County of Donegal, and Section of the East Side of Lough Foyle* (fig. 9).—On that portion of the Irish coast which is most nearly contiguous to the south-western extension of the quartz-rocks and limestones of the Grampians, we have a great development of rocks of a metamorphic character. Almost the whole of the County of Donegal is made up of rocks which appertain to this series; and with them are associated plutonic masses. Of the deposits in this area the greater portion consists of gneissose strata, nearly allied in lithology to the chloritic schists of the S.W. parts of the Grampians.

These chloritic schists, which in geological maps of Ireland are generally termed mica-slates, are subjected to great flexures. They have prevailing N.E.–S.W. strikes; and, on the whole, S.E. dips are predominant. Like rocks of a similar nature, these gneissose rocks of the North of Ireland manifest themselves under such circumstances as to induce the conclusion that they occupy the higher zone amongst the deposits of this region. Beneath these gneissose rocks of Donegal there is seen a thick series of quartz-rocks, having the same strike, and being subject to the same flexures and dips as the overlying strata. In many localities in the North of Ireland, between the quartz-rocks below and the gneissose strata above, there occurs a dark-grey limestone; and in some areas, where the flexures become flattened, this limestone covers a considerable surface. This limestone, which is well seen at Culdaff, on the N.E. side of the Inishowen peninsula, occurs in other localities between the quartz-rocks and the gneissose beds, but has hitherto yielded no fossils.

In this arrangement of the metamorphic deposits of Donegal we have an exact counterpart of the Highland series; and this affinity becomes still more apparent when we examine in detail the section afforded by the N.E. coast of this country from Inishowen Head to Malin Head, the extreme North of Ireland (fig. 9).

Commencing at the S.E. end of this section, we have exhibited the usual chloritic schists of the North of Ireland with the prevailing S.E. dips, frequently the result of reversed flexures, which are numerous in this district. This chloritic schist forms the Mountain of Craignamaddy. Rocks of this nature extend north-westward to the neighbourhood of Tramore Bay, where the quartz-rocks begin to show themselves, having the usual S.E. inclination. These quartz-rocks occupy the coast between Tramore Bay and Dunmore Head; and at the latter spot the chloritic schists again make their appearance, the result of an anticlinal curve in the quartz-rocks, pushing over the latter towards the N.W., and bringing in the small patch of schist which forms Dunmore Head.

Immediately north of Dunmore Head the limestones, dipping under the chloritic schists, occur. These limestones of Culdaff are not seen on the shore, owing to the district being low and covered with sand. At a short distance inland they are very apparent, and marked by flexures, which spread the beds over a considerable area. The limestones here possess the prevalent S.E. dips.

North of Culdaff large masses of trap are seen extending inwards, in a W.S.W. direction, to beyond the village of Malin. On the line of the section N. of these traps, another exhibition of quartz-rocks occurs, intersected by other traps; and this area of quartz-rocks extends for more than two miles, after which chloritic schists again make their appearance. This second mass of quartz-rocks with the prevailing S.E. inclination has had its origin from the same circumstances which gave rise to the area south of Dunmore Head, viz. from an anticlinal pushed over towards the north. These two areas of quartz-rocks, separated from each other by the chloritic schists of Dunmore Head, are seen in the district south-west of Cardonagh, and they form the quartzitic area which is well developed on the east side of Lough Swilly; from whence they extend south-westward to Lough Muck, and terminate in a point flanked on the N.W. by the granite of the Derryveagh Mountains, and on the S.E. by the great area of gneissose rocks.

Continuing the section north-westwards, the chloritic rocks succeeding the quartz series are well seen at Glengad Head. They also form the Mountain of Maheryard, and possess, as regards dip and arrangement, like features to those of the masses of these rocks which occupy the more southern area. A little to the north of Maheryard the quartz-rocks again appear, supporting the chloritic schists, and have a continuous S.E. dip from the junction with the chloritic rocks to a spot called Sandy Port.

This latter surface of quartz-rock is much intersected by traps; and at Sandy Port a well-marked axis is seen, from which *reversed* dips occur. Near this axis the quartz-rocks put on an aspect different from that which they generally assume. They have a pink colour, are much broken up, are devoid of regular arrangement, and exhibit features nearly akin to hornstone. At Sandy Port, traps are seen; but these have not produced the results above alluded to, and such results do not accompany the other outbursts of trap, which are so abundant along this coast.

These changes in the quartz-rocks have originated from plutonic masses; and although rocks of this character are not seen immediately on the north-east coast of Donegal, yet at a short distance inland such rocks occur.

The rock which has produced the hornstone aspect in the quartz-rocks, and given rise to this well-marked axis, is a red syenite, very manifest on the west side of Malin Head; and this red syenite occupies a considerable area in the north-west of the county of Donegal.

From this axis at Sandy Port the quartz-rocks continue north-westward to Ballyhillin, where they are succeeded by the overlying gneissose series.

On the north side of this axis the higher members, which southward consist of chloritic schist, are represented by a *flaggy gneiss*, which is well seen in the precipitous rocks on the north-east side of Malin Head; and lithologically this gneiss is very much allied to the upper gneiss of Sutherland. Traps are very abundant among the rocks which form the north-east extremity of Malin Head; and thick veins of white quartz are also prevalent in this locality.

With reference to the West of Ireland, where rocks consisting of gneiss, limestone, and quartz-rocks are shown to occur, I have not had an opportunity of comparing these as they are exhibited in the County of Mayo with the North of Ireland and with the Highland rocks. But, inferring from the strike and the arrangement of these rocks as they are laid down on the geological map of Ireland, I feel little doubt that they are referable to the same position and sequence as the rocks of a similar nature in the North of Ireland and in the Highlands of Scotland, and that the true position of these rocks is that assigned to them by Sir Roderick Murchison in his "Hypothetical View respecting the Gneissose Rocks of the Southern Highlands" (Quart. Journ. Geol. Soc., vol. xvi. page 238).

P.S. [April 6th.]—Since the above memoir was read, the author has again visited the limestone which is worked at Leny, near Callender, for the purpose of endeavouring to procure fossils from the associated black shales. After a careful and diligent search, no specimens could be detected, although the limestone is now being wrought to a considerable extent. The face at present exposed shows a greater extent of rock than that above referred to,—no less than twelve feet of limestone with thin black shales being visible, and having well-developed black shales both above and below. A dyke of porphyritic felstone, which cuts the limestone very obliquely to the west of the quarry, is also seen on the north side of the limestone.

Although no fossils were seen, the phenomena of cleavage, which are by no means well developed among the rocks constituting the Grampians, are beautifully shown in the shales associated with the limestone in this spot. These possess a cleaved structure to a great extent, having, in some instances, lost all traces of their original bedding. The thin limestones, however, are devoid of this structure, —a circumstance which supports the inference that, although the rocks of the Grampians have been subjected to the pressure which results from great flexures and contortions, the lithological nature of the strata was such, except in the case of the shale-beds, that no rearrangement of particles could take place to give rise to cleavage-planes.

March 6, 1861.

Francis George Shirecliff Parker, Lieut. H.M. 54th Regiment, Roorkee; and J. Gwyn Jeffreys, Esq., 25 Devonshire Place, Portland Place, were elected Fellows.

The following communications were read:—

1. *On the* Succession *of* Beds *in the* "Hastings Sand" *in the* Northern Portion *of the* Wealden Area. By Frederic Drew, Esq., F.G.S., of the Geological Survey of Great Britain.

Contents:

I. Introduction.
II. Wealden Formations in the Meridian and Neighbourhood of Tunbridge Wells.
1. Weald Clay. 3. Wadhurst Clay.
2. Tunbridge Wells Sand. 4. Ashdown Sand.
A. Presence of the Ashdown Sand in the Railway-cutting between Tunbridge and Tunbridge Wells, and the Extent of the Tunbridge Wells Sand to the Northward.
III. Eastward of the Meridian of Tunbridge Wells.
1. Weald Clay. 4. Ashdown Sand.
2. Tunbridge Wells Sand. 5. Hastings Sand around Hastings and Battle.
3. Wadhurst Clay.
IV. Westward of the Meridian of Tunbridge Wells.
1. Weald Clay. 2. Tunbridge Wells Sand, Upper and Lower, with the intermediate "Grinstead Clay."
V. Nomenclature of the Hastings Sands.
1. Dr. Mantell's Nomenclature.
2. Reasons for using the Names now proposed.
VI. Weald Clay of the Neighbourhood of Horsham.
VII. Conclusion. Lithological Characters of the Hastings Sand.

I. *Introduction.*—Having for the last two years been engaged (in the course of the progress of the Government Survey) in examining part of that large tract in the south-east of England which is made by the outcrop of the Wealden strata, and having now become acquainted with many details concerning that formation, I wish to bring before the Society an account of its lithological character and of the order of succession that prevails in it.

As regards this part of England, the Wealden formation has long been divided into three members, namely—

The "Weald Clay," the "Hastings Sand," and the "Ashburnham Beds."

The first, the "Weald Clay," is much the same through all its thickness; where there is variety in it, it has been well described by Dr. Fitton, Mr. Martin, and Dr. Mantell. The lowest member, the "Ashburnham Beds," which may, perhaps, be classed with the Purbeck formation, does not appear in that district in which I have more particularly been engaged. I shall therefore say little of these two, and almost confine myself to the "Hastings Sand," and to the northern part of the Hastings Sand country, a district, 50 miles long and varying from 3 to 12 or more in width, lying between and in the neighbourhood of the towns of Tenterden, Cranbrook, Tunbridge Wells, East Grinstead, and Horsham.

This "Hastings Sand," it is well known, has much clay and a little of other substances interstratified with it; and something has been done towards finding out the order and character of its divisions, especially in certain districts; but these are small in extent and are separated from one another, no good comparison of the beds in each has been made, and some of the accounts given seem to be contradicted by the facts which I have lately observed. I therefore think it well to lay these before you, with my notions as to their bearing on what was before known; and I believe they will do a good deal towards connecting together the various information you are already in possession of, and clearing up some points on which doubt or confusion has been felt.

It will be best first to repeat as shortly as possible the conclusions arrived at by those who have written about these strata.

Dr. Mantell, who had paid more attention than any one else to the Wealden formation, and who was particularly successful in the discovery and the study of its organic remains, gives the following as the succession of beds:—

Weald Clay, stiff brown and blue clay; then the Hastings Sand, divided into—

1. Horsted Sand: light-coloured sand and sandstone.
2. Tilgate Beds: sand and sandstone, gritstone (calcareous sandstone), and clay or shale.
3. Worth Sands: white and yellow sand and sandstone.

The name of No. 1 is taken from a place, which I have not visited, not far from Lewes; No. 2 is called "Tilgate Beds" from Tilgate Forest, some miles east of Horsham; No. 3 is named from its occurrence, according to Mantell, at Worth, near Crawley. In the neighbourhood of Hastings, where the best sections are to be seen, Dr. Mantell recognizes the same series of strata as he observed in the more western parts whence he took their names; and he describes

Horsted, Tilgate, and Worth Beds as having just the same characters in the two districts.

Dr. Fitton, in his valuable paper on the strata below the chalk, gives some detailed sections of what was to be seen on the face of the cliffs west of Hastings; and these have come to be the more important from much of what was then visible being now obscured by the buildings of the town of St. Leonards. Dr. Fitton did not at that time connect what he observed into a system of strata; but subsequently, in a "Sketch of the Geology of Hastings," written by him, he adopted provisionally the same division as Mantell did.

The information given in the older books and papers may be considered as merged in these conclusions of Dr. Mantell and Dr. Fitton: so I need not speak further of them; for I do not wish to give here a history, but an account of the latest and best state of the knowledge of this formation. More lately, however, than all this, Mr. Morris and Mr. Prestwich described to the Society* the cuttings that were being made for the Tunbridge Wells Railway; and, though they were not quite sure that they understood the succession of the beds exposed in them, they gave their idea of what it might be. As the part examined by them is included in that which I intend to speak of somewhat minutely, I will leave the discussion of their views for the present, and pass on to my own description of the rocks.

In giving this, I will first speak of them as they occur in the neighbourhood of Tunbridge Wells—for many reasons a convenient part to begin with; I will then give a short account of what they are on the east of that place; and lastly, we will trace them in the other direction as far westward as where the Hastings Sand dips beneath the Weald Clay.

II. *In the Meridian and Neighbourhood of Tunbridge Wells.*

1. *Weald Clay.*—In the meridian of Tunbridge Wells I find the Weald Clay to consist nearly all of clay and shale of different colours, blue, brown, yellow, &c. It has one or two thin bands of Paludina-limestone, and some calcareous grit and clay-ironstone; the thickness I believe, from what I hear of borings into it at Maidstone, and from what I see of the fall of ground between where its upper beds occur and the outcrop of its base, to be not less than 600 feet †.

* Quart. Journ. Geol. Soc., vol. ii. p. 397. 1846.

† The following are the grounds for this estimate. A boring at Brenchley's Brewery, at the bottom of Gabriel's Hill, Maidstone, which began about at the top of the Weald Clay, went through 500 ft. of clay (passing a water-bearing sand at 100 ft.), and did not reach the bottom. Another boring, at Allnutt's Paper-mill, Tovil, near Maidstone, began at the top of the Weald Clay, passed a water-bearing sand at 115 ft., and went through, on the whole, 600 ft. of clay down to a hard rock, which they did not pierce, and which very likely was the top of the Hastings Sand. Again, the top of the Weald Clay at River Hill, on the Greensand escarpment, is 500 ft. above the sea-level; at Leigh (which bears from River Hill in a direction at right angles to the strike of the beds) the base of it is 80 ft. above the sea-level. Therefore, if the beds were flat between those two places, there would be a thickness of 420 ft.; but it is very likely that there

The boundary between it and the first stratum of the Hastings Sand is sharply defined: in many places, as at the river-bank below Ramhurst Farm near Tunbridge, at Capel on the east of that town, and at Culverden Quarry and Rusthall Common, both near Tunbridge Wells, the clay is seen to rest immediately on good sand or sandstone. At a certain height, however—perhaps thirty feet—above the junction there is a layer of loam with a little sandstone, which may vary from twenty to a very few feet in thickness. This is within what I call "Weald Clay." Between this layer and the stratum-level that I take for the boundary, is stiff clay or shale, sometimes containing lenses of calcareous grit *.

2. *Tunbridge Wells Sand.*—The first layer of the Hastings Sand I call "Tunbridge Wells Sand"; and in using this and other names of my adoption I have been guided by reasons which will best be given towards the end of this paper.

The top of the Tunbridge Wells Sand is hardly seen on the first outcrop of it from beneath the Weald Clay, though at these points—namely, on the left bank of the Medway on the west, and by Sandlin and Capel-bank on the east of Tunbridge—there are moderately good sections; but it is well shown in several parts of that great spread of this subdivision which occurs all around Tunbridge Wells. The top bed is in many places a fine, hard, white sand, with few or no partings or distinction of beds in it, similar in composition to that thick bed of sand underneath the Castle and in the East Cliff at Hastings, though this belongs to another horizon. It is stuff that is difficult to work out, and sometimes requires even blasting; but when separated into fragments, a touch will break it into loose sand. In other places the bed is a soft, generally buff-coloured, or else light-brown building-stone in a massive bed. The gradual change from the first kind of substance (which may conveniently be called "rock-sand") to the other is well seen along two or three different lines—namely, from Tunbridge Wells by Rusthall Common to Langton†, from the High Rocks to the summit of Groombridge Hill, and from Eridge Rocks to Alksford and Sherlock's. I have measured at different places 25, 35, and even 48 feet of the rock-sand, and of the equivalent bed when sandstone 10, 12, or 16 feet, generally in one thick, pretty hard layer. Beneath this well-marked top bed come still sandy beds, but not massive ones like the first; for the greater part of the Tunbridge Wells Sand may be described as soft, buff or light-brown sandstone in beds of half a foot, 1, 2, 3, or more feet thick, interstratified with beds of loam, thin beds of clay, and now and then some rather loose sand. The whole thickness of the subdivision seems to be 160 or 180 feet. I judge it to be as much as this

is a general dip to the north (in one or two places I have seen the beds dipping in that direction); if it were only half or three-quarters of a degree, the thickness would be 600 feet. I am indebted to Mr. Bensted, of Maidstone, for the information about the borings.

* In the following localities:—River-bank nearly a mile east of Leigh; railway-cutting north of Penshurst Park; near Fordcombe, &c.

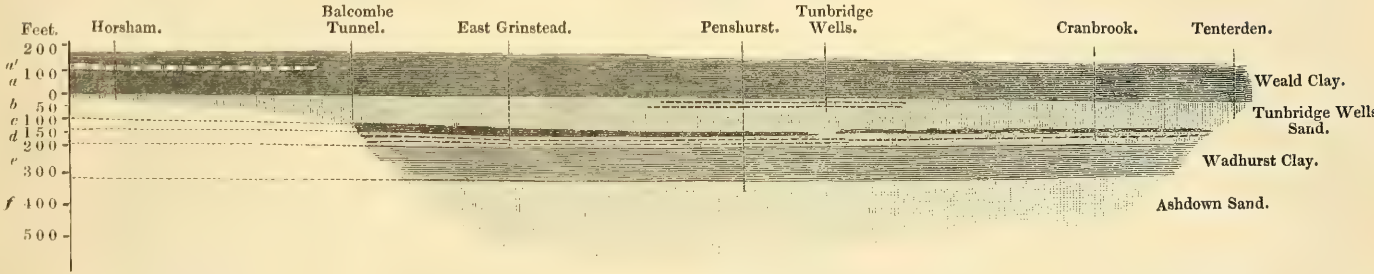
† Marked *Lengthington Green* on the Ordnance Map.

at Tunbridge Wells, from the great descent there is between the outlier of Weald Clay at the top of the Common, by the corner of Bishopsdown, and the valley of the Wells; and even in this the base of the sand is not reached, while the dip is in that direction which would make out the thickness more than the fall of the ground. At Groombridge Hill too, where the strata are about flat, there is 180 feet of vertical height from the top to the bottom of the sand. At Eridge Rocks, however, and at some other places, there can hardly be so great a thickness.

I should here mention those natural sections so well known to every one who has been in the neighbourhood of Tunbridge Wells: they are lines of projecting rock sometimes showing a quite perpendicular face. From their having a grey weathered surface, and from the way in which the vegetation is combined with them, clothing and hanging over the summits, they form, in several places, exceedingly pretty groups. All of these (namely those on Tunbridge Wells and Rusthall Commons, Eridge Rocks, Harrison's, Penn's Rocks, &c.) belong to one stratum, namely the top bed of the sands that I have before described; and it is to be remarked that these bare rocks occur where the bed is not in its hardest form (namely a good sandstone), but they are almost in every case composed of rock-sand, which would seem to resist the degrading action of the weather by the solid mass it presents without planes of division. It will generally be found that the rocks are capped with an outlier of clay, which is of course the Weald Clay. There is one more circumstance about the Tunbridge Wells Sand which I would have borne in mind, because it bears on a question we shall come to discuss; it is that sometimes at a level quite low down in this subdivision another bed of rock-sand occurs; it does not, however, form any natural rocks. It may be seen by Groombridge, Speldhurst, Nashes near Penshurst, and at other places.

3. *Wadhurst Clay.*—We now come down to a clay stratum, which I call "Wadhurst Clay." The bottom of the sand is generally loamy, this being the passage (not a very gradual one) to the clay that succeeds. This last is, both in the upper part and through all its thickness, stiff brown clay, or brown or blue shale; it ends sharply against the next sandy stratum, good clay or else shale resting on sand or sandstone. The thickness was proved by a well-sinking at Pellet Gate, Pembury, to be 160 feet; but I do not think it is everywhere quite so much; I should say that in the neighbourhood of Tunbridge Wells it varied between that and 120 feet. There occurs a little of three different kinds of stone in this clay,—first, a calcareous grit, or a fine, hard, calcareous sandstone, which is seen in thin beds every here and there; but just in the neighbourhood of Beech Green, Withyham, it forms beds of two or three feet, much worked for roadstone. Secondly, a shelly limestone, containing *Cyrena* chiefly, of which I only saw a few two- or three-inch layers. Thirdly, a smooth grey clay-ironstone, generally in small nodules or layers of nodules. It was this kind of ironstone, and chiefly stone from

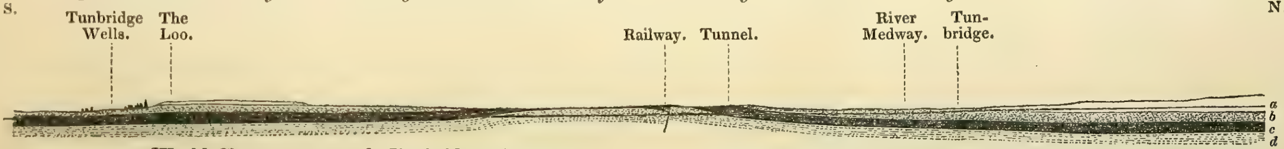
Fig. 1.—*Diagram-section showing the Succession of Beds in the Wealden Formation on the North side of the Weald.* Distance about 60 miles.



a. Weald Clay. *a'.* Horsham Stone. *b.* Upper Tunbridge Wells Sand. *c.* Grinstead Clay.
d. Lower Tunbridge Wells Sand. *e.* Wadhurst Clay. *f.* Ashdown Sand.

The lines of strong dots indicate the horizons to which the Rock-sand (forming weathered "Rocks" near Tunbridge Wells, East Grinstead, and other places) belongs.

Fig. 2.—*Section along a line nearly North and South from Tunbridge Wells to Tunbridge.* Distance about 8 miles.



a. Weald Clay. *b.* Tunbridge Wells Sand. *c.* Wadhurst Clay. *d.* Ashdown Sand.

this very stratum, that was dug to supply the furnaces that once abounded in this part of the country. The shallow round pits by which it was extracted can yet be seen in many of the woods; they must not be confounded with the large openings, now partly filled up and much overgrown, or else forming ponds, that were made, also many years back, to get shale, or "marl" as they call it here, with which it was the custom to dress the land. It may be that in digging this out they put aside and carried to the furnace whatever ironstone was met with: all tradition, however, points to the small shallow holes as the source of the ore, which went (and still goes) by the name of "iron-mine" or "mine-stone," while the pits are called "mine-pits," and the large places are everywhere recognized as "marl-pits." I should mention that on the south of Wadhurst Tunnel, in the railway-cutting, I saw a thickness of 15 feet of sandstone and loam in this clay, and once or twice besides I have seen traces of a similar bed. It is likely enough that the same sort of thing occurs in other places, where it escapes notice (for in a clay country deep sections are always scarce); yet I have seen enough to be convinced that this bed is very nearly all of clay.

4. *Ashdown Sand.*—The "Ashdown Sand" comes next; it has no character to distinguish it from the Tunbridge Wells Sand; the two can only be separated by regarding their positions with respect to the Wadhurst Clay, or, if this fails on account of faults being present, by slight and quite local differences. It is a similar collection of layers of sandstone and loam with an occasional bed of rock-sand; and it has this further resemblance, that the top is in many places a good thick bed of rock-sand: this is well seen in four or five of the valleys lying on the north of the road from Wadhurst to Mark Cross, which reach through the clay to the Ashdown Sand. I do not think I have found this bed making natural rocks like the one at the top of the other sands.

Clay-ironstone occurs occasionally in the upper sandy subdivision; but yet more is found in the Ashdown Sand. A good deal may be seen in the heaps brought up from the Wadhurst Tunnel and thrown out above it; and in the railway-cutting, a mile and a half further down the line, it has lately been worked to see if it would answer to transport it to the North. On Ashdown Forest, too, it occurs frequently, generally with a coating of brown iron-ore; there are two or three pits where it is now being dug for roadstone; and I have heard that about here like stone used to be extracted from the sand for smelting.

A bed of clay and shale occurs in these sands; it is seen at several points south of Frant and along the north of Ashdown Forest; at the latter part it appears to be 30 feet or more in thickness.

These sands have a great spread about Ashdown Forest; it is indeed the central district of the Hastings Sand, where these low beds rise and make the highest ground of any in the whole formation.

The deep valleys that cut across Ashdown Forest reach down to such a depth as to expose, I should think, 250 feet in thickness of the sands, without reaching to their base; for the lowest beds seen (those at Crowborough Mills seem to be so) are of just the same sort of sandstone and loam. Some miles north and north-east of this there are other tracts of this sand, of very irregular forms; they are brought to the surface by one or more anticlinals that run somewhat east and west. There are two inliers * of it quite near to the country of the Weald Clay itself; namely, one a few miles to the south-east of Edenbridge, and another that stretches from Penshurst to beyond the line of railway between Tunbridge and Tunbridge Wells.

A. *Presence of the Ashdown Sand in the Railway-section from Tunbridge to Tunbridge Wells, and the Extent of the Tunbridge Wells Sand to the northward.*—It is just at this part that the beds were examined by Mr. Morris and Mr. Prestwich, whose description of them is printed in the Society's Journal †. In making a comparison of this with the results of my own observations, I must refer you to the transverse section, fig. 2, p. 276. Mr. Morris and Mr. Prestwich began their observations by the Tunbridge Tunnel; and just on the south of it they saw sandstone beds coming from underneath a great thickness of clay and shale. Passing on through several cuttings, and rightly interpreting a fault (the throw of which, however, they somewhat overrated), they came to shale again, this time overlain by sandstone. This, however, they take to be a lower bed of shale (partly from its differing from the other in being unfossiliferous), and they consider this sandstone, which continues on to Tunbridge Wells, to be in the same part of the series with that they first saw, accounting for the position of the shale by supposing a second fault, concealed in the valley. I am, however, convinced (and I have no doubt that Mr. Prestwich and Mr. Morris would have come to the same conclusion if they had been able to extend their observations for a few miles to the east and west of the railway) that these last shales, coming from underneath the Tunbridge Wells Sand, are the upper part of the bed of which the shales at the Powder-mill and Tunbridge cuttings are the lower (namely the Wadhurst Clay), and that the sandstone underneath them at the latter places is the top of the Ashdown Sand. This I have proved by tracing the shale around this inlier of sand which I observe to come from underneath it; while the shale, in its turn, is covered by the mass of sand from Bidborough to Tunbridge Wells, as well as by like sand on the other side of the valley, and is capped by two or three outliers of sand nearer to Tunbridge. The difficulty in the way of this explanation, which they

* I doubt if this word *inlier* is enough in use to be allowed to pass without explanation; for I have never seen it in print. It means a space occupied by one formation which is completely surrounded by another that rests upon it. It is useful to have a word that will express this; and "inlier" is a very appropriate one; for the circumstance to be named is the exact converse of "outlier," which is an isolated mass surrounded by a formation that underlies it; and the advantages of "inlier" are manifest over such a phrase as was used in the same sense by the late Mr. P. J. Martin, namely, "outlier by protrusion."

† Quart. Journ. Geol. Soc., No. 8, vol. ii. p. 397.

rejected on that account, is that there are few signs of such a thickness of sand as that of all the Tunbridge Wells beds on the north of the Tunbridge Tunnel; I have, however, seen sand resting on the clay close there, and not far off are one or two sections showing no inconsiderable thickness of it. The greater part of the space between that and the Weald Clay is flattish ground, covered either by a loamy alluvium or by gravel; and, of course, sections through this are scarce; but I have seen some sand as far away as a quarter of a mile to the N.W. of Tunbridge Town. The Tunbridge Wells Sand, then, must have its first outcrop along here, though there is no great feature of ground such as one would expect; for along this part, where there is a special line of elevation, the ground has been denuded to quite a low level.

III. *Eastward of the Meridian of Tunbridge Wells.*

1. *Weald Clay.*—The foregoing, then, are the beds that are found in the neighbourhood of Tunbridge Wells—using the word "neighbourhood" in a somewhat wide sense: we will now look at them in the more easterly part of their outcrop (for I have traced them for fifteen or twenty miles in that direction), taking them in the same order as before. The outcrop of the lower part of the Weald Clay is in flat ground, where there are few sections of any depth; and, besides, it is hidden in many parts by some thickness of gravel; I therefore cannot speak as to its exact character, but I find a pretty well-marked line between the clay and the Tunbridge Wells Sand. East of Tunbridge Town I quite lose sight of that loamy and sandy bed which I said there was, on the other side, some forty feet up in the clay.

2. *Tunbridge Wells Sand.*—The top of the Tunbridge Wells Sand loses its rocky character a little before we get as far east as Brenchley, and becomes sandstone and loam not different from the rest of the division, which itself is so much the same as I have before described that I need hardly speak of it more. It may be mentioned, however, that at a level that seems to be somewhat below the middle there is seen in some places a thin bed of clay and loamy clay, partly red in colour, and underneath it a bed of rock-sand or else thick-bedded sandstone. I cannot say for certain, but I think that the clay-bed is not always present, but lies in patches, while the rocky character of what is underneath it is more persistent. The two beds can be traced as far east as the town of Tenterden. See fig. 1, p. 276. Hardly any evidence could be obtained about the thickness of the division; but it seems, from the space it occupies, to be much the same as at Tunbridge Wells.

3. *The Wadhurst Clay.*—The Wadhurst Clay is also like what it is at Tunbridge Wells. I have but one thing new to remark on it: the very top of it (the few feet below the junction with the sand) is, in some places, especially near Cranbrook, of a rather red clay. The thickness seems to be as much as 160 or 170 feet at Goudhurst, and rather less in other places.

4. *Ashdown Sand.*—The Ashdown Sand, too, is the same as before. It still is rocky at or near the top; that is to say, thick-bedded sandstone or rock-sand is found not many feet below the base of the Wadhurst Clay; for the rest, it is such that one cannot distinguish it from the Tunbridge Wells Sand. I have not seen any great thickness of it. The bottom has not been reached.

5. *Hastings Sand around Hastings and Battle.*—These three beds, then—two of sand with one of clay between them—spread over a considerable area, without undergoing any great change; and beyond this part, where I have myself examined them, Mr. Charles Gould, who was then on the Geological Survey, made out at the same time their succession about Hastings and Battle and further to the north-west; and he has described them in his notes in much the same terms that I have used for them, though it would seem that the clay in the middle (the Wadhurst Clay) is there of a less thickness, and has a greater admixture of loam and sand, than in the more northerly part. Mr. Gould and myself, though the districts we were upon were quite separated, worked up to and identified a section in an intermediate spot, so as to be sure of the true relation of the beds in the two districts. Quite lately I have been in the very easterly part, at Rye and thereabouts, and have found similar strata with the same general character, and which may therefore be considered to belong to all the Hastings Sand that is east of Tunbridge Wells.

IV. *Westward of the Meridian of Tunbridge Wells.*

1. *Weald Clay.*—Next in course we will follow the strata westward from our first starting-point. The Weald Clay, as a whole, continues the same. A sandy bed of no great thickness occurs near the bottom, which appears to be a continuation of the one I mentioned before: it may be traced pretty distinctly as far as Lingfield; and so may the horizon below it, which I fix on for the top of the Hastings Sand; but west of Lingfield, for a length of about eight miles, neither line is so definite. There is a good deal of loam in the bottom part of the Weald Clay, and what clay there is is mostly sandy clay: the line I have taken for the boundary is where this doubtful stuff ends and the purer sand begins. It must be remembered that it is within quite narrow limits that its right position is doubtful. Beyond Three Bridges Station the change from clay to sand becomes more marked again, and keeps so till near Horsham, where there is some difficulty in pointing out the exact boundary. It is clear, though, that the sand does not extend more than a mile beyond that town, but, dipping gently westward, disappears beneath the Weald Clay, the boundary-line changing its direction and trending to the south-east.

2. *Tunbridge Wells Sand, Upper and Lower, with the intermediate Grinstead Clay.*—Of the Tunbridge Wells Sand, we will first speak of the upper half. The bed of rock-sand at the top of it continues for some miles; it forms a fine line of rocks at Redleaf, Penshurst,

and is again exposed in Chiddingstone Park. West of this, for a few miles, the outcrop of this part of the series is interrupted by some faults. At Stamford End, Edenbridge, rock-sand is again seen at the horizon that I am speaking of: but this is about its last point; for further west the top of the Wells Sand is thin-bedded sandstone, with some loam interstratified; and of this same description is all the upper half of this division. Taking the Tunbridge Wells Sand as a whole, near the place it is named from, I find, on tracing it west, that a bed of good stiff clay appears in it, and gets thicker and thicker the further one goes in that direction. This clay, which I call "Grinstead Clay," is first seen distinctly in Penshurst Park and in the road-cutting that runs along the west side of it. Here I measured a thickness of 17 feet of clay, and I saw below it a bed of white rock-sand; while the Wadhurst Clay is not far beneath. Near Tunbridge Wells itself there is here and there some red, rather loamy clay, with thick-bedded sandstone beneath it; and this I take to be the same Grinstead Clay thinning out and occurring only in patches, while I refer the lower bed of rock-sand that I, some way back, said there was in the lower part of these sands, to the horizon of that which underlies the "Grinstead Clay" at Penshurst. It will be remembered too that I mentioned a thin varying bed of clay, *some of it red*, resting on a bed of rock-sand or thick sandstone, as occurring about Cranbrook; this is probably the equivalent of it too. Following the same bed westward for some miles, I see little of it on the north, on account of the faults; but more to the south a succession of outliers enables us to get a good idea of it. North of Hartfield it may be 20 ft. thick; at the most easterly of some outliers that occur north of Forest Row it is 30 ft.; at the next somewhat more than that is seen, though the top has been denuded; while at East Grinstead the thickness is probably 40 ft.; and here it is worth while to look more closely into its character. At the very top of it there is red clay, which is a very useful mark by which to recognize this stratum; lower down it is brown clay, or brown shale, or blue shale; it everywhere makes very stiff ground, and it ends sharply against the sand that is below. This sand, as at Redleaf, is either rock-sand or thick-bedded sandstone, in a mass of 30 feet or so thick. Sections of it may be seen in most of the lanes about East Grinstead; but it is also shown in natural sections at Ashurst Wood Common, where it forms lines of rocks. In other places, too, it juts out from the side of the hill, and a few miles to the south, at a place near West Hoathly that bears the name of "The Rocks," it makes two long lines of them—the edges of a projecting angle of ground between two deep valleys, that rival in beauty those of Tunbridge Wells; and indeed there is such a resemblance between this and the groups at the last place, that almost every one would at first say that they belonged to the same stratum—an error that would probably be confirmed on the finding of a capping of clay to each set. I have, however, no hesitation in saying that the two beds or their equivalents are separated by a thickness of strata of more than 100 feet. This is the conclusion to which I have come after a very detailed mapping of the ground between the two localities; and the Geological Survey Map, which will before long be published, will show that the course of the beds, though much interrupted by faults, is consistent only with this theory,—the mass of the Wadhurst Clay being not far below the rock-bed, and a great thickness of sand above the clay that rests upon it. There is about 30 feet of sand that is not rocky, and making only a gentle slope, below the harder bed; and then comes the Wadhurst Clay. These changes of the strata can be best understood by a glance at the vertical section, fig. 1, p. 276, in which each of the rock-beds is represented by broken lines: their appearance and dying out, and the relationship of the clays above them, will be at once comprehended.

About the lower beds in this part I have not much to say; they have changed so little from what they are at Tunbridge Wells. The Wadhurst Clay is just the same mass of clay and shale with clay-ironstone in it (which stone has been dug a good deal near East Grinstead), and with a little calcareous grit and shelly limestone,—the whole being from 100 to 130 feet thick. The Ashdown Sand does not come much west of Ashdown Forest, where I have before described it: the top of it around some inliers there are on the north-east of Grinstead is not rocky, but of the ordinary thin-bedded stone or else of looser sand; there is, however, a rock-bed lower in the sands, as well as a subordinate bed of clay; in general character it is just as before.

There is a gradual dip of the beds from Ashdown Forest both to the north and to the west, so that the lower beds disappear as we go in either direction; the Wadhurst Clay skirts round the forest and dips down at about West Hoathly; while the course of the Grinstead Clay is three miles or so to the west. This bed, however, is again reached by a deep valley, along which the Brighton Railway has been made, exposing the best section of it I have seen. At the cuttings at each end of Balcombe Tunnel the Upper Tunbridge Wells Sand is seen underlain by purple clay which passes downwards into blue shale. More than 40 ft. of this Grinstead Clay can be measured on the north side; and there is probably about 50 ft. of it on the whole; for in this cutting the bottom of it is not reached: in the southern one, however, the rock is seen coming from underneath.

V. *Nomenclature of the Hastings Sand.*

1. *Dr. Mantell's Nomenclature.*—We are now in a position to compare what I have related with the accounts of Dr. Mantell, and to discuss the question of what names may be proper for these strata. As I have before said, Dr. Mantell makes out two sands separated by "Tilgate Beds," which he describes as sand, calc-grit, and blue clay, in this descending order. I was at first puzzled to know whether the strata he met with hereabouts were the Tunbridge Wells Sand with the Grinstead Clay in it, or the two thick sands with the

Wadhurst Clay between them. Tilgate Forest, which he speaks of as the great locality for the fossiliferous gritstone of his "Tilgate Beds," is upon the uppermost sand of all, even if we take the name to mean, as indeed it does, a greater space than is so marked on the Ordnance map; and the neighbouring forest, St. Leonards, is on the same strata, except that some of the valleys may just reach down to the Grinstead Clay. I am told that most of the fossils he collected came from near Cuckfield; and Mr. Hay of the Geological Survey, who has been engaged upon that part of the country, informs me that they were got from two distinct beds—one of them the Grinstead Clay, the other much higher up in the series.

The sands which he named from the village of Worth, near here, and placed next below the "Tilgate Beds," belong to what I have called "Lower Tunbridge Wells Sand;" while the beds about Hastings, which were called "Tilgate" and "Worth" by Dr. Mantell, are much lower down, and do not come to the surface within some miles of these places. This misconception (which could hardly have been avoided without mapping the country step by step between the two parts, on account of there being no important break in the series, and almost no lithological difference between the several sands and clays) renders it, I think, necessary to disuse the names of "Tilgate" and "Worth" Beds; and with them must go that of "Horsted," taken from quite another part, and perhaps accurate in itself; since these, even if they were applicable to this particular neighbourhood, could not be used for the beds further east without leading to great mistakes. I will now shortly say why I adopted the names that I have been using.

2. *Reasons for using the Names now proposed.*—Taking the eastern part first: about Tunbridge Wells the upper sands occupy a great space; they form nearly all the hills near; and their top bed makes those conspicuous rocks that I have spoken of. I think, therefore, their name is well taken from that place. The clay beneath them is chiefly found in the valleys about there; but near the large village of Wadhurst, about seven miles to the south-south-east, it spreads over some tolerably high ground, which is indented by a series of valleys that expose a great thickness of it, and at last reach down to the sands below; and its position with regard to these can also be well seen in the cuttings at the ends of the Wadhurst Tunnel. I have on these accounts thought it well to take the name of *Wadhurst Clay* for the second stratum. The lower sands make very high ground, are spread over a large area, and show a very great thickness on Ashdown Forest, which is the central part of all the Hastings Sand country: no name, I think, can be better for these than *Ashdown Sands*. The bed of clay that appears in the Tunbridge Wells Sand, and thickens to 50 ft. to the westward, may well be called *Grinstead Clay*, from its occurring on the north side of the town of East Grinstead, and making as large a spread near there as anywhere else, and from its relation to the lower beds being well seen in that neighbour-

hood. This clay of course divides the sand into *Upper* and *Lower Tunbridge Wells Sand.*

VI. *Weald Clay of the Neighbourhood of Horsham.*

I have said that the Hastings Sand occupies the surface hardly further west than Horsham, dipping beneath the Weald Clay about a mile beyond that town; in most maps, I believe, it is made to go some miles further on, and the hills about Horsham are put down for Hastings Sand. This difference is due to a slight misunderstanding of the nature of the strata there. The flat on which the town is built is on the uppermost beds of sandstone, which lie very flat, but yet dip gently to the north, and west, and south. The hills around, the most conspicuous of which is that of Den Park, are chiefly of clay; there is 120 feet in thickness of it; but they are capped with a hard stratum, which is no doubt the cause of their standing out as hills. The beds that compose this are not more, taken together, than 10 feet in thickness. They are clay with two or three layers of sandstone, which contain large flat masses of calcareous grit, just like what occurs in the Wadhurst Clay. Many quarries are dug in this; and the ripples and other appearances the hard stone shows, have been described by Mantell, Lyell, and others. This set of beds occupies a great space in the form of a table-land slightly sloping from the edge of the escarpment above Horsham in the same direction as the dip, the width being in one place as much as two miles, and varying from that down to 100 yards. I should have some hesitation in thinking that all this ground was occupied by a stratum no thicker than what I have said, but that Mr. Hay (who was the first to perceive its true position) and myself have traced its upper and lower boundaries for many miles, and have examined every section of it without finding any evidence of, or any necessity for supposing, a greater thickness than I have named. If, therefore, a division is made into Weald Clay and Hastings Sand, this Horsham stone must, at least for the north side of the Weald, be included in the former; for here it is only a 10 ft. bed 120 feet up in the clay, and further east there is nothing but clay at the same horizon; for, as we go away from Horsham in that direction, the feature it makes becomes less important, and the stone is little worked, and evidently thins away: the last signs of it are at Crawley. Behind (on the north of) the course of this bed from near Horsham to Crawley, there is another line of hill which might easily be mistaken for the feature of the Horsham stone; it is in fact, although of greater altitude than any made by this stratum, entirely of clay, which is yet higher in the series, the Horsham stone making a step projecting from beneath it. The thickness of Weald Clay above the level of the stone-bed is very great indeed; I reckon it to be about 500 feet, which will give altogether 600 feet or so for the Weald Clay here, the same as its thickness was found to be in Kent.

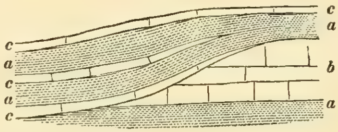
VII. *Conclusion. Lithological Characters of the Hastings Sand.*

To conclude: I should like to give a short summary of the general character of the formation, and to call attention to those points by a study of which we may get a fuller knowledge than we now have of the sources of the material of which it is composed, and the conditions of its deposit.

Plainly divided (as the Wealden formation is, in spite of the admixture of the two substances to some extent through all its parts) into clayey beds and sandy beds, we shall find in each of these certain details that are worthy of notice. The clay is generally shaly, not hard, but in soft fine laminæ; these are sometimes, though not generally, separated by an accumulation of the cases of *Cyprides*: the thinness of the flakes made Prof. E. Forbes give the substance the very expressive name of "paper-shales." At some parts, however, there is a mere mass of clay without any stratification seen. I believe it is always so when the clay is of that crimson-red colour, ranging from that to purple, which occurs at some definite horizons; the origin of which, whether existing so in the rocks from which the clay was derived, or acquired more lately, I should much like to hear accounted for. The clay strata, as before said, are varied with occasional bands of calcareous matter, either pure, as shelly limestone, or mixed with a large proportion of sand, and making a calcareous sandstone. Lastly, it contains irony matter, sometimes in the form of concentrically flaking nodules of brown iron-ore, but more often as layers of nodules of clay-ironstone.

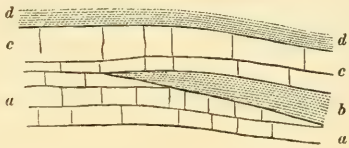
Of the sandy beds there is more to be said. The sand itself is nearly always extremely fine, almost an impalpable sand. On this account it bears itself somewhat in the same way that clay does as regards the presence of water: instead of absorbing it like an ordinary sand, it becomes a pasty mass that can be moulded like a very light clay, and this though it contains no alumina. In appearance, as well as to the touch, it a good deal resembles the "Loess" of the Rhine. The roads that are made with the soft sandstone are in dry weather thick in dust, but after a good deal of rain in a complete slush of mud. A small proportion of clay mixed with this, as it is in many of the loams that are met with in this formation, makes one think the compound to be much more clayey than it really is. Sometimes a coarser sand occurs, and this is found more useful for building-purposes, from its having the quality of *sharpness*; and less frequently there are layers of pebbles in the sand, usually about the size of a pea, but now and then as large as a walnut. I have found this coarse deposit and the less than usually fine sand generally in one of the beds of rock-sand. And here I would remark (but I do not know if the fact is of any import) that these rock-beds in almost every case of their occurrence underlie one of the beds of clay. Hydrous peroxide of iron occurs in small quantities in the sandstone, generally in thin wavy flakes, sometimes more diffused, so as to make a ferruginous sandstone; and occasionally clay-ironstone is seen. Lignite is found in the sandy beds, either in small fragments scattered through a sandstone or loam, or in a bed, from a fraction of an inch to a foot or more thick, which does not continue for very many yards; and, again, there may be carbonaceous matter diffused through a layer of loam or of clay. Loam occurs in large quantities in the sandy beds; it is in beds some feet thick, interstratified with the sandstone; the two substances interchange along the same stratum-level, the beds varying very much within short distances. I think that few continue for long of the same character, so as to be recognized. Figs. 3 and 4 are two sketches of sections which show plainly how the changes take place, either by the thinning off of a bed

Fig. 3.—*Section in the Tunbridge Wells Sand, near Strawberry Hill, Tunbridge Wells.*



a, a. Sand in laminæ. *b.* White Sandstone, 3½ feet. *c, c.* Sandstone.

Fig. 4.—*Section in the Ashdown Sand, at Riverhall, near Frant.*



a. Rock-sand. *b.* Loam in laminæ. *c.* Sandstone. *d.* Shaly Sandstone.

and the wedging in of a new one, or by the overlying beds lapping over its edge and occupying what would be its place if it were continued.

Lastly, the sand often shows oblique lamination in different directions; and it probably was accumulated in that way in other cases where there are no signs of it from the deposit being homogeneous. Ripples, too, are frequent, often well-marked, and striking in various ways.

But notwithstanding these changes, it holds good that the beds which, on the whole, are sandy, and the beds that are chiefly of clay, lie in the order which I have described, as represented in the section, fig. 1, p. 276.

2. *On the* Permian Rocks *of* South Yorkshire; *and on their* Palæontological Relations. By James W. Kirkby, Esq.

(Communicated by Thomas Davidson, Esq., F.R.S., F.G.S.)

[Plate VII.]

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§ I. *Introduction.*—In the present communication I propose to speak of the geology and palæontology of the Permian strata that lie between the towns of Pontefract and Knottingley, on the one hand, and Tickhill and the village of Maltby, on the other. In doing so my chief objects are, first, to endeavour to determine the equivalency of the subdivisional groups of these strata with those of the adjoining county of Durham; and second, to throw some additional light, if possible, upon the distribution of Permian species south of the Durham area. Towards the accomplishment of these objects I have made two visits to the district in question—one in 1854, and the other during the summer of 1859.

Prof. Sedgwick has already described the geology of this region in his admirable memoir "On the Geological Relations and Internal Structure of the Magnesian Limestone*." Prof. Phillips has also noticed some of its features in a short paper "On the Geology of Ferry Bridge and its Vicinity," published about the same period as the preceding†. And since the publication of these papers, Mr. H. Clifton Sorby and Mr. Edward W. Binney appear to have pursued investigations in the same district, though the results have not been published‡. Sir Roderick Murchison has also alluded to certain points of its geology in the last edition of 'Siluria§.'

* Trans. Geol. Soc., 2nd ser. vol. iii. pp. 37–124.

† Philosophical Magazine, vol. iv. 1828.

‡ See Prof. King's remarks on *Mytilus squamosus*, *Bakevellia antiqua*, and *Dentalium Sorbyi*, Mon. Perm. Foss. pp. 160, 170, 218.

§ Siluria (1859), pp. 348, 349.

The continued researches that have been pursued of late years in the Permian strata of Durham have carried our knowledge of their palæontology and geology much in advance of that of the Permian formation of Britain generally; and nowhere is the contrast greater than with the Yorkshire portion of that formation, more particularly in regard to its palæontology: and it is with a desire to add something to what we already know of the Permian strata of the district specified that I make the following observations. The exhaustive investigations of Prof. Sedgwick, however, have left little to add to the full account of the lithology of this district given in his memoir; so that I am obliged to confine my attention chiefly to its palæontology. It is a delicate, and certainly a difficult, matter to notice its geology at all after Prof. Sedgwick; and I only do so somewhat briefly in order to show how it would seem best to co-ordinate the subdivisions of strata with those of the Durham series, and for the sake of more fully explaining some of the facts relating to the fossils.

§ II. *Permian District in South Yorkshire.*—Before proceeding further, it may be remarked that, in examining a geological map, the Permian strata of Yorkshire are seen to traverse the centre of the county in a long narrow stripe, running about N.N.W. and S.S.E., apparently almost wearing out in the former direction, and gradually increasing in width towards the south until a maximum of about five miles is attained, at which width they continue into Nottinghamshire. Their western boundary—most ably described by Sedgwick—usually forms a well-marked escarpment, often of comparatively great elevation above the low-lying plain of the coal-measures to the west*. Their eastern boundary, where they dip beneath the Triassic strata, is more difficult of determination, being often masked by alluvium or marsh-land. As the general dip of the strata is easterly, their order of succession can easily be examined by passing transversely across their outcrop. This I did repeatedly during my peregrinations in this region, and always found the same sequence of beds.

Sections near Doncaster.—In going west from the town of Doncaster, which stands on the alluvium-covered western edge of the New Red Sandstone, the first rocks we meet with are some thin flaggy beds of limestone, with occasional bands of red and green marls, which, as a group, we readily recognize as the "Brotherton Beds" of early geologists. After passing extensive quarries of this limestone (which, by the sinking of wells and other artificial excavations, is known to have a deposit of marl and gypsum at its base) we come to an extensive series of thick and irregular beds of limestone of a whitish or yellowish colour and a subcrystalline texture. These beds form a group of much greater thickness than the preceding member, and are described by Prof. Sedgwick under the name of the "Small-grained Dolomite." Still further west we meet with a series of pisolitic, cellular, arenaceous, and compact limestones, some of which are fossiliferous. The lower beds of this latter group rest immediately

* As at Barnborough Cliff, Hooten Pagnell, and several other places, where the prospect westward is most magnificent.

upon a deposit of false-bedded, incoherent sandstone, which it is not difficult to identify as the Lower Red Sandstone or Rothliegendes. Beyond this are the Coal-measures.

There are several routes across the outcrop of the beds, with Doncaster for the starting-point, that show this succession of strata. It is well shown on the south side of the Don on the road leading by Hexthorpe, Warmsworth, and Conisborough to Hooten Roberts, and on the north bank of the same river along the road by Newton and Sprotborough to Cadeby,—the numerous quarries on each route affording a good general section. A magnificent section is to be obtained by traversing the valley of the Don from Doncaster to a little beyond Conisborough; and yet another, and one of the best, which Sir Roderick Murchison has already noticed*, on the South Yorkshire Railway between the points last-named. In all these lines of section the same superposition occurs,—and not only here in the valley and on the banks of the Don, but north as far as Pontefract, and south to Roche Abbey, which are the limits of the district I have examined. North of the Don an excellent section is to be obtained in the Vale of Went, from east of Little Smeaton to Wentbridge; and to the south there is one almost equally instructive from Tickhill to Maltby.

From the investigations of Sir Roderick Murchison and the officers of the Geological Survey, it would appear that there are some beds of red sandstone and marl overlying the Brotherton Limestone of this district, which also belong to the Permian formation†. And, though I have not been able to identify these beds myself, I include them in the following list of subdivisions as the uppermost member of the Permian series of South Yorkshire on the authority of these observers.

To recapitulate, then, the Permian series of South Yorkshire seems capable of being naturally divided, in the descending order, as follows (see fig. 1):—

1. Bunter Schiefer.
2. Upper Limestone—including the Brotherton Beds and Lower Red Marl and Gypsum.
3. Small-grained Dolomite.
4. Lower Limestone.
5. Lower Red Sandstone.

As Prof. Sedgwick has already described the physical geology of these subdivisions, it will scarcely be required of me to notice them at any great length. It is requisite, however, that I should give a description of these strata as far as necessary for their features to be understood, and for the proper appreciation of their relations to each other and to the subdivisions of the Permian group of Durham. For fuller descriptions I refer the reader to the memoir of Prof. Sedgwick in the 'Transactions' of this Society for 1835.

1. *Bunter Schiefer.*—Soft red sandstone and marl (Murchison and Geol. Surveyors).

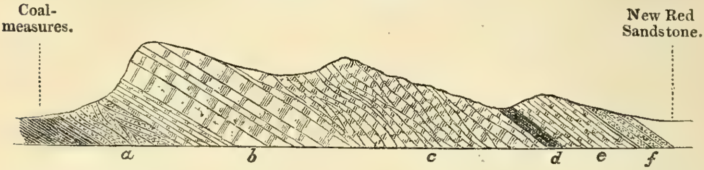
2. *Upper Limestone or Brotherton Beds, and Lower Red Marl.*—The Brotherton Beds are a series of thin, flaggy limestones, usually hard and compact, and of a yellow or grey colour. The surface-

* Siluria, p. 348.

† Siluria, p. 326, and Table of Strata, p. 432.

planes are generally a little apart, and often coated with red, green, or purple clays or marls; bands of marls similarly coloured are occasionally met with among the limestones (Hexthorpe).

Fig. 1.—*Sketch-section of the Succession of the Permian Strata in South Yorkshire.*



f. Bunter Schiefer. *e.* Brotherton Beds. *d.* Lower Red Marl and Gypsum. *c.* Small-grained Dolomite. *b.* Lower Limestone. *a.* Rothliegendes or Lower Red Sandstone.

In certain localities some of the beds contain casts of *Axinus dubius* and *Myalina Hausmanni*, together with some obscure remains that seem referable to *Algæ*.

The Lower Red Marl and Gypsum immediately underlie the preceding beds. They consist of beds of red and variously coloured marls with bands of gypsum, are apparently unfossiliferous, and are rarely seen in section.

The slight importance which the Lower Red Marl seems to hold in the physical geology of this district, the absence of any palæontological feature belonging to it, and the occasional presence of red and other coloured marls in the Brotherton Beds have induced me to describe it along with the last-named deposit, and to suggest the propriety of considering it as part of the same subdivision. I do this with much diffidence and some doubt, being aware that such a view is opposed to the opinions of Prof. Sedgwick and the officers of the Geological Survey.

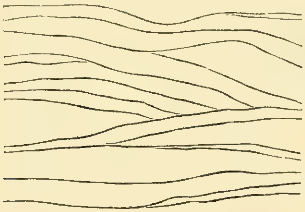
The Brotherton Beds are well exposed at Knottingley, Womersley, Hexthorpe, Wadworth, and many other localities, being much worked for lime-burning and road-repairs.

3. *Small-grained Dolomite.*—A crystalline, subcrystalline, or compact limestone of a slightly yellow, cream-coloured, whitish or lustrous grey tint. Thickness of beds ranging from 3 feet to 1 foot and under. Stratification very irregular, beds thickening to maximum, and thinning out suddenly; it being almost the exception for one stratum to appear in section for a moderate distance: planes of stratification curiously pitted. Among the uppermost beds occur intercalations of greenish clay or marl a few inches thick (Cliff Quarry, Brodsworth).

This limestone seems to be entirely void of fossils, except inferiorly towards its junction with the Lower Limestone, where faint traces of them occur (Town Quarry, Conisborough); and in these lowest beds there is also a tendency towards an oolitic character, that is never to be observed in the middle and upper parts, though much less evident than in some of the beds of the Lower Limestone.

The very peculiar stratification of the Small-grained Dolomite is mentioned by Prof. Sedgwick as having been noticed by him at Steetly, near Mansfield, and other places*. It is a common characteristic of it generally. In the old quarries at Warmsworth sections most illustrative of this character are to be seen, one of which is represented in the accompanying woodcut.

Fig. 2.—*Sketch of the False-bedding in the Small-grained Dolomite at Warmsworth Quarry, near Doncaster.*



The different beds are interwoven as it were, and form about as curious a piece of undisturbed stratification as it is possible to conceive. Beds which have a maximum thickness of 2 feet actually thin out in each direction within a space of 20 feet, their places in the section being taken by others almost equally brief in continuance. It is thus difficult to trace a line of bedding for any great extent; and within the traceable extent even of the most continuous beds the line is often a curved one of great irregularity. Indeed some of the sections in the Warmsworth Quarry†, as well as in others, are neither more nor less than highly illustrative instances of false-bedding—a character common enough in arenaceous deposits, but very unusual in limestones.

Another peculiar feature of this limestone is the manner in which its planes of stratification are pitted—almost as though worked by an artist, Prof. Sedgwick likening it to "artificial rustic work‡." These surfaces are covered as thickly as possible with little pits or hollows, that extend for $\frac{1}{8}$th or $\frac{1}{4}$th of an inch into the limestone, with diameters of about the same measurements (that is, when largest), their depth and width often being much less. I have little doubt myself of this feature being due to some peculiar concretionary action, analogous to that which gave the Upper Limestone of Durham its remarkable structures.

For architectural purposes the limestone of this member is perhaps unequalled in England. It can be obtained in blocks of any moderate size, has a texture and hardness highly suitable for delicate mason-work, is of a beautiful tint, and will withstand almost any amount of weathering. It is therefore scarcely to be wondered at, that many of the finest edifices in England are constructed of it. Its quarries

* Trans. Geol. Soc., 2nd ser. vol. iii. p. 84.

† The quarry here referred to lies at the west end of the village, and just to the south of the main road leading to Conisborough.

‡ Trans. Geol. Soc., 2nd. ser. vol. iii. p. 84.

of Huddlestone, Bolsover, Steetly, and Roche Abbey are amongst the most famous in the country*.

Its maximum thickness must be about 200 feet or more. This thickness it would appear to attain on the right bank of the Don, a little to the south of the river. In other places it cannot be near so thick, as between Hampole and the Great North Road; indeed, the variability in the amount of space between the outcrops of the Brotherton Beds and the Lower Limestone, allowing for difference of position in surface, indicates a great variability in its thickness in its north and south range. For this reason, and on account of its irregularity of bedding, I am disposed to look upon it as having originated in a comparatively shallow sea. Its general structure implies the influence of currents of great inconstancy, and altogether reminds us of that which may be supposed to characterize those submarine banks, such as the "Dogger Bank" of the German Ocean, that accumulate in water of no great depth, under the influence of variable currents, at some distance from land.

The Small-grained Dolomite can be easily examined in numerous localties west of Doncaster, where it is well exposed in the picturesque crags of the Don, and in the quarries that have been opened on the banks of that river. Amongst other localities may be named the quarries at Warmsworth, Levit Hagg, Cusworth, Outmoor, Cockhill, Sprotborough, Roche Abbey, and Brodsworth; the cliffs in the Vale of the Went, and on the banks of the Don east of Conisborough.

Professor Sedgwick notices it as occurring also at Mansfield, Bolsover, and Steetly further south, and at Huddlestone, to the north of these localities.

4. *Lower Limestone.*—Between the beds just described and the

* It should be remembered, however, that even this limestone, like all other rocks of sedimentary formation, requires selection; for intercalated among the beds of good stone are others which do not possess the most important property of capability to withstand atmospheric action. And not only so, but it is exceedingly difficult to distinguish such beds from the best. It thus happens that a certain percentage of stone of an inferior quality is often supplied to the builder along with a large quantity of good, and is used by him without suspicion of the evil. I saw an illustration of this in the new church of St. George at Doncaster, which is chiefly built of this limestone, where the surface of stray blocks in the exterior was already in a state of decay when I visited it only one year after it had been opened. Much of the stone used in the erection of the New Houses of Parliament is from quarries (Huddlestone and Bolsover) of the Small-grained Dolomite; and it would seem as if stones from its worst beds had been supplied rather extensively. For I cannot think that stone from its best beds would ever have shown such signs of decay as it is asserted the stone of the river-front of the palace already shows, even if we allow the atmosphere of the metropolis to be very deleterious indeed. And, notwithstanding all the obloquy that has been thrown upon the parliamentary commission appointed to select the building-stone for fixing upon a magnesian limestone, and this in particular, there can be no doubt they were right in their choice—the fault not being in the stone chosen, but apparently in the neglect of the architect in not seeing that it was taken from the right beds. To obtain a good supply of stone of uniform good quality, it is necessary to appoint some one at the quarry to select the beds to be worked, and to see to the honesty of the contractor or quarryman in working only those selected,—the only difficulty being the requisite knowledge to determine which are the superior; and this, I conceive, is rather to be attained by long practical experience than from experiments in the laboratory.

Rothliegendes is a series of limestones of various characters which may be conveniently grouped as the Lower Limestone. Some of these are oolitic, pisolitic, and nodulous (Brodsworth, Moorhouse, &c.); other beds may be termed polyzoan, being almost solely composed of fragments of *Polyzoa* (Brodsworth, Cadeby, &c.); others are cellular and unstratified (Pontefract); and others, again, are compact (Hickleton, Conisborough, &c.), or arenaceous (Bag Hill, Pontefract, Barnborough Cliff). Perhaps there is no single section of the Lower Limestone that shows the whole of these beds, though by examining a mile or two of the escarpment, or a few transverse sections of the limestone west of the Small-grained Dolomite, limestones of all the characters mentioned may be met with, besides others that are more or less modifications of these. In the vicinity of the Don the upper portion of this subdivision is a soft, thick-bedded, yellowish, oolitic limestone,—the roe-like grains being in some beds intermixed with irregularly rounded concretions as large as peas, and in others with concretionary nodules an inch or more in length, it being not uncommon to find the same stratum oolitic, pisolitic, and nodulous. Several species of fossils occur in these beds, generally as casts. A little lower down are some thick beds equally as soft as the former, which are chiefly composed of comminuted *Polyzoa*, principally of the species *Acanthocladia anceps*. Beneath these and immediately above the sandstone are other beds, which are thinner, darker-coloured, and more compact, or rarely earthy. Numerous remains of a few species of fossils occur in these beds, but often most imperfectly preserved *.

In other places more to the north, especially about Pontefract and at Wentbridge, the upper part of this subdivision is soft, yellowish, amorphous, and full of irregularly shaped sparry cavities. Under it are some thick beds of a harder limestone in which are immense quantities of *Gervilliæ* (casts). Below these are some thin strata of hard, compact, pisolitic, and arenaceous limestones, charged with the remains of *Axinus dubius* and *Gervillia antiqua*. These latter beds are seen to rest upon the Rothliegendes at Bag Hill, opposite to Pomfret Castle, where they become arenaceous and almost graduate into sandstone.

The junction of the lower beds of limestone with the Rothliegendes can be seen to great advantage in several sections in and about Pontefract, as Prof. Sedgwick has pointed out. It can be well studied in section to the south-west of the town in some road-cuttings and quarries, particularly in one on the Carlton and Ackworth road. Another interesting section is to be seen in an obscure old quarry on the escarpment, just above the pretty little hamlet of Carlton, where the lowest limestone, which is cellular, void of stratification, and charged with a few badly preserved fossils, rests upon an irregular surface of the sandstone, the latter being yellowish, moderately hard, and false-bedded. The lowest limestone in this instance appears to

* Prof. Sedgwick describes the most characteristic of these beds in section ix. of his "Great Middle Deposit of Yellow Magnesian Limestone." Trans. Geol. Soc., 2nd ser. vol. iii. p. 93.

be the equivalent of the amorphous limestone previously mentioned; and from this we infer that the beds found beneath that deposit in some of the sections about Pontefract are here wanting.

One of the most interesting sections illustrative of the junction of the lower limestone with the Rothliegendes is at Wentbridge, in the cutting on the Great North Road. The latter deposit is here seen towards the south end of the cutting, forming a large portion of the cliff on each side of the highway, and capped by a few feet of limestone, which, by the ascent of the road and the dip of the beds, gradually increases in quantity to the north-east—the sandstone disappearing, and fresh beds of limestone coming in that direction. The beds of limestone immediately above the sandstone are thinnish, of a brown colour, compact in texture, and contain the remains of *Axinus dubius* and *Gervillia antiqua*. These strata occupy a few feet of the section and are superimposed by a stratum of hard limestone about 6 feet thick, full of the casts of *G. antiqua*. Other massive beds follow, some of which are fossiliferous; and above them are some thinner beds of soft and friable limestone, also with casts of *Gervilliæ*.

On other parts of the escarpment, as at Hampole Stubbs *, the Rothliegendes is covered by some thick beds of reddish limestone of a compact, subcrystalline, or oolitic character, and which contain several species of fossils, among others *Axinus dubius* very large. But in this section the oolitic beds of the member occur much nearer the sandstone than in other places to the north and south.

Another section showing the two deposits in juxtaposition is found on the escarpment between Hooten Pagnell and Hickleton, where a series of thin-bedded, hard, crystalline, unfossiliferous limestones of a brown colour are seen to rest immediately upon the Rothliegendes, which is here soft and very incoherent. The structure of these limestones rather resembles that of the Brotherton beds, the strata being of similar thickness and hardness as those of that member. As a section of the Lower Limestone it certainly differs most widely from any other that I met with on the escarpment or elsewhere in South Yorkshire †.

Viewing the Lower Limestone as a whole, we perceive it to be more inconstant in structure, composition, and general character, than any of the other subdivisions of the series. The sections just noticed suffice to prove its mutability; and more comprehensive details would only tend to make the fact more evident. Nevertheless, though the most variable member of the Permian formation in South Yorkshire, it can always be easily distinguished from either of the limestone members that overlie it, its features being peculiar and well marked.

Most of the limestones of this group are included along with the

* The locality of Hampole Stubbs, which is on the road leading from Doncaster to Wakefield, and just beyond Little John's Well, would seem to be identical with the "Stubbs Hill" of Sedgwick.

† This section occurs in a plantation scarcely a mile south of Hooten Pagnell, and near to a footpath that winds along the escarpment from that village to Hickleton.

Small-grained Dolomite in the third subdivision or "Great middle deposit of Yellow Magnesian Limestone *" of Prof. Sedgwick. Some of the most inferior appear to be placed in his second subdivision, the "Marl-slate and thin-bedded and nearly compact limestone †".

The organic remains of this subdivision possess considerable interest, as our knowledge of the distribution of the Permian fauna in this area is almost solely based upon them, there being but three species of the Yorkshire list that range beyond its limits. The state of preservation of the fossils is generally as casts, it being exceedingly rare to meet with examples in a more perfect condition. Their extreme abundance—at least of certain species—on some horizons has been alluded to in the cases of Wentbridge and Brodsworth. And so far as we may judge, this abundance extends over comparatively wide regions; for in the case of the Gervillia-bed, which occurs so thick at Wentbridge, I have traced it over a distance of twelve miles, having seen it also at Pontefract (Bullhill Quarry), Emsall, Hooten Pagnell, Brodsworth, Hickleton, and Barnborough Cliff. The polyzoan beds I have not traced so far; but they are to be found at Brodsworth (Freestone Quarry), Hampole, and Cadeby. Further particulars of the fossils of this member will be given in another part of the paper.

As an approximation, 120 feet may be given as the probable thickness of the Lower Limestone; it being questionable whether it ever exceeds that estimate, though scarcely so as to whether it sometimes reaches it.

Amongst other localities affording good opportunities for studying its various beds, may be mentioned the numerous sections alluded to in the neighbourhood of Pontefract, which illustrate the cellular and arenaceous forms of it; and the quarries at or near Brodsworth, Hampole, Hampole Stubbs, Emsall, Conisborough, Cadeby, Moorhouse, Hooten Pagnell, and Hickleton the oolitic, polyzoan, and compact beds.

5. *Rothliegendes or Lower Red Sandstone.*—A deposit of yellow, red, grey, or variegated sandstone; fine-grained, or rather coarse in texture; of irregular structure, false-bedding being common; and though sufficiently firm to form a soft building-stone in some localities (Pontefract, Barnborough Cliff, and Wentbridge), yet often very soft and incoherent (Wentbridge, Moorhouse, and Hickleton).

The Lower Red Sandstone of South Yorkshire differs little from that of Durham, except, perhaps, in being a little more coherent and finer-grained. And in no case have I observed any decided instance of its unconformability to the overlying limestone, though it is not always easy to say whether it is conformable or not, its stratification being subject to such irregularities. There is no section on that portion of the escarpment I examined that affords much support to the opinion of those who would separate it from the Permian strata on account of its unconformability to them—rather to the contrary.

This deposit is so well described by Prof. Sedgwick that I would rather direct attention to his remarks on it than attempt further description. It is easy of examination along the escarpment in

* Trans. Geol. Soc., 2nd ser. vol. iii. p. 81. † *Loc. cit.* p. 79.

South Yorkshire; and it is nowhere better exposed, nor more characteristically developed than about Pontefract *. In quarries on the north and west of that town it is worked as a building-stone, being of about similar coherency as the equivalent beds in the vicinity of South Shields, which are likewise used by the builder. Among other localities on the escarpment south of Pontefract, may be named those at Carlton, Wentbridge, Hampole Stubbs, Moorhouse, Hickleton, Barnborough Cliff, Cadeby, &c.

§ III. *Comparison of the Permian Strata of South Yorkshire with those of Durham.*—Having now given some details illustrative of the characters of the subdivisions of the Permian series of South Yorkshire, it will be of interest to attempt their co-ordination with the subdivisions of the equivalent series of Durham.

Commencing at the base, we have the lower red sandstone, the equivalency of which with the lower red sandstone of Durham, as well as with the typical Rothliegendes of Germany, has been so long known to geologists as not to require special pointing out. Indeed the researches of Prof. Sedgwick clearly show the Yorkshire and Durham beds to be portions of one deposit, in all probability yet continuous. We have thus contemporaneous subdivisions at the base of each series. If we pass on to the Brotherton beds, the highest calcareous member, we find that it agrees in position with the upper limestone of Durham, and, besides, that it is characterized by the same fossils, and by a similar paucity of them. For these reasons I look upon the Brotherton beds as the equivalent of the upper limestone, being fully persuaded that such agreements could not have occurred in deposits of different periods. Thus we have the lower limestone and small-grained dolomite confined between two determined horizons, with the marl-slate, compact limestone, and shell- and cellular limestone of Durham as equivalents. Of these I look upon the lower limestone as being parallelized by the marl-slate and compact limestone, and the small-grained dolomite by the shell and cellular limestone. The marl-slate has no special representative in Yorkshire. And, though it is possible that its deposition may have preceded the commencement of that of the lower limestone, I see nothing that leads me to suppose that it did. In classing it as the equivalent in part to that Yorkshire member, I rely upon the fact of its being the commencement of calcareous beds in the Durham series, just as the lower limestone is in the series of Yorkshire, and on the probability of the accumulation of arenaceous sediment having been consummated and that of calcareous sediment begun about the same period in both regions. It is the compact limestone, however, that is to be considered as principally equivalent to the lower limestone. In regarding the shell- and cellular limestone of Durham as the equivalent of the small-grained dolomite, it may be objected that the great difference that exists in their palæontological features is opposed to such an identification. To this I would reply that the dif-

* The fine deep soil in which the people of Pomfret grow the liquorice-root to manufacture the "Pomfret Cakes," for which, among other things, their town is so famous, seems to be largely composed of the débris of this member.

ference is one of distribution, similar to the differences seen in the distribution of marine life in recent seas—the bottoms of which, we know, offer many examples of great irregularities in the distribution of the various forms of life that people them. To conclude, we have the Bunter Schiefer of Yorkshire apparently parallelized by some obscure and little-understood beds of red sandstone which occur in the south-east portion of the county of Durham, superior to the upper limestone, and which have been classed by Mr. Howse * as Permian under the name of Lower Bunter.

In arriving at these conclusions I have chiefly been guided by the relative positions of the subdivisions of each series. Indeed, in this instance, with such differences in the palæontological and structural features of the subdivisions, vertical position is almost the only test that can be used in attempting to parallelize them; and in series of strata, or rather in portions of the same series so little apart as the two compared, vertical position would seem to be as good a test as any that could be used. I would also observe that, in regarding subdivisions to be equivalents, I also consider them to be of contemporaneous deposition. Thus the Brotherton Beds and Upper Limestone not only represent the last deposition of calcareous sediment in each area during the Permian era, but are looked upon as contemporary. It is not, of course, supposed that the accumulation of each commenced and ceased at exactly the same periods in both areas, but that the bulk of each subdivision was synchronously deposited. [*See the Tabular View of the Permian Strata of Durham and South Yorkshire*, p. 298].

§ V. *Remarks on the Fossils.*—I now proceed to notice the species I have met with in this district.

Cephalopoda.

1. Nautilus Freieslebeni, Geinitz, Neues Jahrbuch, p. 637, pl. 11. fig. 1.

Syns. *N. Bowerbankianus*, King; and *N. Theobaldi*, Geinitz.

A cast of a body-chamber of a young individual of this species occurred at Brodsworth. It is rather less than half-an-inch long, is a little more compressed medianly than Durham specimens of similar age, and shows traces of a shallow median sulcation.

This is the only Cephalopod I have met with in Yorkshire; but Prof. King quotes it from Aldfield, Yorks. (in the cabinet of Prof. Phillips)†.

Gasteropoda.

2. Turbo helicinus, Schlotheim, Petrefactenkunde, p. 161.

Syns. *Turbo Mancuniensis*, *T. minutus*, and *Rissoa obtusa*, Brown; *Littorina Tunstallensis*, Howse; and *Turbo Thomsonianus*, King.

Full-grown specimens of this species in Yorkshire have five whorls, and are about one-sixth or one-fifth of an inch in length. At Ham-

* Ann. and Mag. Nat. Hist., 2nd ser. vol. xix. p. 34.

† Mon. Perm. Foss. of England, p. 220.

Tabular View of the Permian Strata of Durham and South Yorkshire.

Subdivisions.	Durham.	South Yorkshire.
1. Bunter Schiefer	*Red Sandstone* overlying the Magnesian Limestone in the S.E. portion of the county? (Howse). Thickness 50 ft.?	*Red Sandstone* and *Marl* near Doncaster and Tickhill (Geol. Survey). Thickness 50 ft.?
2. Upper Limestone	*Yellow, Concretionary,* and *Crystalline Limestone* of Marsden, Fulwell, Roker, Hartlepool, &c.* Thickness 250 ft.	*Brotherton Limestone* and *Lower Red Marl* and *Gypsum* of Brotherton, Knottingley, Womersley, Wadworth, Tickhill, &c. Thickness 120 ft.
3. Middle Limestone	*Shell-* and *Cellular Limestone* (*Fossiliferous* and *Pseudo-brecciated Limestone* of King) of Tunstall and Humbleton Hills, Ryhope, Galley's Gill, Down Hill, Claxheugh, &c. Thickness 150 ft.	*Small-grained Dolomite* of Vale of Went, Lound Hill, Cusworth, Levit Hagg, Roche Abbey, Warmsworth, &c. Thickness 200 ft.
4. Lower Limestone	*Compact Limestone* of Pallion, Whitley, Pensher, Houghton-le-Spring, Ferry Hill, Thickley, &c. Thickness 200 ft.	Lower Limestone of Pontefract, Wentbridge, Hampole, Emsall, Brodsworth, Conisborough, Micklebring, &c. Thickness 120 ft.
5. Kupfer-Schiefer	*Marl-slate* of Claxheugh, Down Hill, Midderidge, Ferry Hill, &c. Thickness 10 ft.	
6. Rothliegendes	Lower Red and Yellow Sandstone of Tynemouth, Claxheugh, Hylton Castle, &c. Thickness 100 ft.	Lower Red, Yellow, and Variegated Sandstone of Pontefract, Hickleton, Cadeby, &c. Thickness 100 ft.
Total thickness	760 ft.	590 ft.

* In a table of Permian and Triassic strata which appeared in a former volume of this Journal (vol. xiv. p. 225), the *concretionary* and *crystalline limestone* is erroneously stated to occur in Yorkshire; and the *fossiliferous limestone* is quoted as being found in Nottinghamshire, in which county the *marl-slate* is also said to occur. It may not be unimportant to point out, more especially as the statements are made by an officer of the Geological Survey, that these stratigraphical groups are not known to occur out of Durham, the two first-mentioned being confined to the north of that shire. In the remarks accompanying the same table another slight misstatement is made, where the *Rothliegendes* is said to be confined to the Western and Midland Counties, the author evidently having forgotten that the Lower *Red Sandstone* of Durham and Yorkshire has been identified with the *Rothliegendes* by Sedgwick, Murchison, King, Howse, and all who have written on it.

pole immense quantities of young and probably rather dwarfed specimens are to be had, some portions of the limestone being literally full of them; and as all these specimens are testiferous, and many of them in a perfect condition, they have afforded me a good opportunity for studying some of the variations of form and character to which this species is subject. The following remarks are therefore solely based upon these materials.

The common form is usually as wide as long, with a large body-whorl, a short, depressed spire (which occupies less than half the entire length), and a large umbilicus. The whorls are ventricose and rather flattened behind; the body-whorl increases rapidly and has two prominent central ribs, bounded on each side by others of less strength, which characterize the species; the apex is obtuse; the aperture orbicular with a slightly reflexed pillar-lip.

Many of the specimens are proportionally longer (the spire being drawn out a little and the body-whorl of less width), and have the whorls rounder and the spiral ribs of uniform strength.

Another variety is without spiral ribs, or with very faint indications of them, and has the whorls somewhat shelving behind, most prominent a little below the median line, and well rounded in front, with a narrow, flattish region bounding the suture.

There are numerous intermediate forms that are more or less modifications of the three noticed, whose differences they serve to connect by numberless slight gradations. This is strikingly the case with the differences observed in the strength of the spiral ribs, it being possible to form series of specimens showing their gradual obliteration; and so it is with the differences seen in the size of the spire, and with those of the rotundity of the whorls. Indeed, it is almost easier to pick out specimens showing some slight differences than specimens which show none.

The Hampole specimens invariably have a more obtuse apex than those of Durham, the first and second whorls being flatter compared with the succeeding ones.

The generic position of this species, like that of several other Permian univalves, is still somewhat uncertain. It has been placed in *Turbo*; and its general resemblance to the shells of that genus induces me to allow it to remain there. Its resemblance to *Littorina*, to which it has also been referred, is perhaps almost as great. And it is only right to mention that the operculum of this shell has never been found, which is better explainable on the supposition of its being horny, like that of *Littorina*, than calcareous like that of *Turbo*. There is, however, no instance on record of the operculum of any of the Permian Gasteropods having occurred in England or Germany.

Loc. Pontefract, Hampole Stubbs, Moorhouse, Pickburn, Brodsworth, Conisborough, and Barnborough Cliff. Taken by Prof. Sedgwick between Marr and Hickleton*; and by Prof. Phillips at Aldfield †.

* Trans. Geol. Soc., 2nd ser. vol. iii. p. 118.
† Mon. Perm. Foss. of England, p. 205.

3. Rissoa Leighi, Brown. Pl. VII. figs. 1–6.
R. Leighi, Brown, Trans. Manchest. Geol. Soc., vol. i. p. 64, pl. 6. figs. 9-11.
Syns. *Rissoa Gibsoni* and *R. pusilla*, Brown.

Typical specimens of this minute species are ovately conical in general form; with four, or rarely five, flatly convex smooth whorls, that increase quickly in length and width, and which are divided by a deepish and slightly oblique suture. One half of the length is occupied by the body-whorl, which has a well-rounded basal slope; the spire is conical, with rather a blunt apex. The aperture is nearly oval and of moderate size, the outer-lip being strongly arcuate, the pillar-lip somewhat curved, and reflected, with a slight umbilical chink behind it.

Length $\frac{1}{8}$ inch; breadth $\frac{1}{12}$.

There are other specimens almost obovate in form, with convex whorls, more depressed spire and obtuse apex. Others, again, have a large body-whorl, rounded whorls, and also an obtuse apex.

An examination of a type specimen of *Rissoa Gibsoni* from the Lancashire Permian beds (kindly lent me by Mr. Binney) has led me to place that species along with the one I am noticing, of which it seems to be but an enlarged form.

The *Trochus pusillus*, Geinitz, of the Unter Zechstein, is a related form, but undoubtedly distinct from the present. So it would appear is the *Turbo Permianus*, King, of the Shell-limestone of Durham.

Rissoa Leighi has only occurred to me at Hampole, where it is not rare in the beds containing *Turbo helicinus*. It is found in greater plenty in the Permian marls and limestones of Colyhurst near Manchester*. It has also been met with under its *Gibsoni* form by Prof. King, at Tullyconnell†.

4. Turritella Altenburgensis, Geinitz. Pl. VII. figs. 9, 10.
Turbonilla Altenburgensis, Geinitz, Verstein. deut. Zech. p. 7, tab. iii. figs. 9, 10.
Syns. *Loxonema fasciata*, King; *L. Geinitziana*, King; *Turritella Phillipsii*, Howse; *T. Tunstallensis*, Howse; and *Rissoa gracilis*, Schauroth.

Specimens of a minute turreted shell are not rare in the Lower Limestone at Hampole. Like the individuals of other Gasteropods from this locality, they are evidently young individuals, and somewhat stunted in growth.

These specimens are minute, turreted, and smooth. They have only five whorls, rarely six, which increase gradually in length, and somewhat quickly in breadth. The whorls are ventricose and equally rounded; the suture is deep, rather wide, and oblique. The body-whorl is about as long as one-third of the entire length. The aperture, which occupies rather more than one-fourth of the length of the shell, is obovate, being rounded behind and rather produced in

* Messrs. Binney and Brown in Trans. Manch. Geol. Soc., vol. i. p. 63; and Prof. King in Mon. Perm. Foss. of England, pp. 205, 206.
† Journ. Geol. Soc. of Dublin, vol. vii.

front; the outer lip is strongly convex; the pillar-lip is slightly convex, and a little reflected; behind it is a very minute umbilicus which in some specimens is scarcely observable.

Length $\frac{1}{12}$ inch; breadth $\frac{1}{26}$ inch.

In the adjoining quarries of Moorhouse and Hampole Stubbs other specimens of what is evidently the same species occur, twice or thrice as large as those just described, and with a greater number of whorls. These specimens are always in an imperfect condition.

These Yorkshire *Turritellæ* agree very well with Geinitz's figures and description of *Turbonilla Altenburgensis*, their general width, perhaps, being a little less compared with their length. They also very much resemble the specimens found by Prof. King in the Tullyconnell limestone, and referred by him to this species. There is a much greater difference, however, between them and the *Turritellæ* of the Shell-limestone of Durham, as there also is between the latter and those of Germany. The Durham examples are much more finely developed, ranging from half-an-inch to an inch in length, and with from 8 to 12 whorls; their aperture is also different, being more angulate by the greater straightness of the pillar-lip. Still I think that the Durham specimens may likewise belong to this species, their differences being such as we may easily suppose to be due to their higher state of development. I do not wish to assert this opinion with much dogmatism, though it seems the most probable to me: and I would add that it is in a similar spirit that I class with this species the various forms indicated by the synonyms at the head of these remarks. It is my opinion that the whole of them are referable to the present species—it apparently having the right of priority; and this is also the opinion of other Permian palæontologists, whose views are of more worth than my own*. Still it should be acknowledged that the question is one of some difficulty and not easy of solution; and that there is, even yet, much to be said in favour of the specific distinction of some of the forms here included as synonyms.

5. Chemnitzia Roessleri, Geinitz, Jahres. Wetter. Gesell. 1850–51.
Syn. *Loxonema Swedenborgiana*, King, Mon. Perm. Foss. p. 210.

A single impression of a fragment of this species occurred at Hampole Stubbs. The specimen shows five whorls strongly ribbed transversely. It is about $\frac{1}{5}$th of an inch in length. The apex is not shown, neither does the largest whorl of the impression appear to be that of the body-whorl. Nevertheless the specimen possesses sufficient character to allow the species to be determined,—the form of the whorls and their transverse ribs being unmistakeably those of *C. Roessleri*.

This species is found also in the Unter Zechstein and in the Shell-limestone of Durham.

* See Mr. Howse on *T. Altenburgensis* in Ann. and Mag. Nat. Hist., 2nd ser. vol. xix. pp. 446–448; and Baron von Schauroth in Zeitschr. d. deut. Gesell. 1856, pp. 236–244.

6. Straparollus Permianus, King, Mon. Perm. Foss., p. 211, pl. 17. figs. 10, 11, 12.

I procured five or six specimens of this species at Hampole. They are as large as the Durham examples, and have three much compressed and rapidly increasing whorls, a large body-whorl, and a slightly elevated spire. In the latter respect they differ somewhat from the majority of the Durham specimens, in which the spire, though still low, is higher, as it also is in examples from the Unter Zechstein of Germany. All the specimens are deeply and largely umbilicated, and have apparently an almost orbicular aperture.

7. Natica minima? Brown. Pl. VII. figs. 7, 8.
Natica minima, Brown, Trans. Manch. Geol. Soc., vol. i. p. 64, pl. 6. figs. 22, 23, 24.

Three specimens of a smooth shell with three whorls have occurred to me at Hampole. They most nearly resemble the *Natica minima* of Brown. The whorls are ventricose, rather oblique, flattened behind and rounded in front; the body-whorl is very large, and the spire short; aperture apparently suboval, outer-lip convex, pillar-lip nearly straight.

The condition of these specimens is not such as will allow me to speak positively in thus referring them to this species. Nor are the figures and description given by Capt. Brown such as afford much aid in their identification. A specimen of the shell, with which I have been kindly favoured by Mr. Binney, does not look much unlike a squat form of *Turbo helicinus*. Nevertheless there is a possibility of its representing a distinct species; and as there is also a possibility of these Yorkshire individuals proving to be the same, I refer them for the present to it—doing so, however, with considerable doubt.

8. Chiton Loftusianus, King, Mon. Perm. Foss. of England, p. 202, pl. 16. figs. 9–14.

I have a posterior plate (cast) of a *Chiton* from Brodsworth, and an intermediate one (cast) from Moorhouse, which appear to belong to this species. The former is rather narrow, and has an elevated and reflexed apex. The latter is obtusely angulated medianly, and has its posterior and anterior margins almost at right angles to the dorsal line. The shell of these plates appears to have been somewhat thick; and the posterior plate, which is the largest, must have belonged to an individual about five-eighths of an inch in length.

Two plates of a *Chiton* are mentioned by Prof. King as having occurred in a Permian limestone at Kirkby Woodhouse in Nottinghamshire*.

9. Dentalium Sorbyi, King, Mon. Perm. Foss. of England, 1850, p. 218.
Syn. *Dentalium Speyeri*, Geinitz, Ueber den Zechstein der Wetterau, 1852, in the Jahres. der Wetterau. Gesell. for 1850–51.

Not rare in the Lower Limestone at Hampole Stubbs. Specimens

* Mon. Perm. Foss. of England, p. 203.

are not well preserved, being either casts of the interior, or impressions left in the matrix after the decay of the shell. They are half an inch or less in length, and are slightly curved, more so posteriorly than towards the aperture; they taper gradually, and have apparently been smooth.

Prof. King first described this species from a specimen discovered by Mr. H. Clifton Sorby at Conisborough.

More than a year ago I found a *Dentalium* in the Shell-limestone of Durham, which evidently belongs to this species. It is testiferous, of the same length, of similar curvature, and smooth like the examples just noticed. It perhaps increases a little more rapidly in width, and is more acuminate posteriorly than they; but these differences seem of little import.

There does not appear to be much doubt as to this species being identical with the *Dent. Speyeri* of Geinitz, which occurs in the Unter Zechstein and Zechstein-Dolomit of Germany. Specimens from these deposits, sent to me by Baron von Schauroth as those of *D. Speyeri*, show little variation from English examples. And I have also compared the latter with drawings of type specimens with which I have been kindly favoured by Dr. Geinitz, but can detect nothing that will constitute a specific difference.

Loc. Hampole Stubbs, Conisborough (*Sorby*).

Conchifera.

1. Gervillia antiqua, Münster; Goldfuss, Petrefacten, part 2. p. 126.
 Syns. *Bakevellia tumida*, King; *Avicula inflata*, *A. Binneyi*, and *A. discors*, Brown.

Two forms of this species occur in Yorkshire. One is longer than wide, rather inflated, with a shallow curvature in posterior margin, and a deep byssal sinus. The other is wider than long, rather flat, and with a byssal sinus not so deep as the first. Neither is found above half-an-inch wide, generally less. The surface of both is marked with the regular, finely raised lines of growth so characteristic of the species in Durham.

The relative thickness of the shell appears to have been greater in the Yorkshire individuals than in those of Durham. The muscular impressions and pallial lines are thus often very clearly indicated on the casts. The hinge-teeth are also very instructively shown in many specimens.

In one quarry near to Pickburn I obtained specimens of the more elongate form which assume the character of the *Bakevellia tumida* of King,—the valves being very tumid, the hinge-line of great width, and the shell altogether more irregularly grown than in type specimens of the species.

G. antiqua occurs in immense quantities in the Lower Limestone, associated with remains of other *Gervilliæ* apparently belonging to the species *keratophaga*. At Bull Hill Quarry near Pontefract, and at Wentbridge, their remains almost solely form thick beds of limestone. It is almost invariably in the state of casts, and generally in detached valves.

It occurs at Bull Hill, Bag Hill, and other localities about Pontefract, at Wentbridge, Hampole Stubbs (Stubbs Hill, *Sedgwick*), Hampole, Moorhouse, Pickburn, Brodsworth, Conisborough, Hooton Pagnell, Emsall, Barnborough Cliff, Cadeby, Braithwell, and near Micklebring, all localities of the Lower Limestone, and in all of which it is common.

2. Gervillia keratophaga, Schlotheim, Densch. Akad. Münch., vol. vi. p. 30, pl. 5. fig. 2.
Syn. *Bakevellia bicarinata*, King.

Specimens of this species occur more rarely than those of the preceding. They never attain the size of the largest Durham specimens, though in common with those they possess the same obliquity of valves, forked posterior margin, and prominent and somewhat distant lines of growth that characterize the species.

It occurs at Brodsworth, Pickburn, and, I think, in other localities; but the preservation of the specimens is such as will not allow me to speak positively on the matter. Prof. King gives the neighbourhood of Pontefract as a locality for it.

3. Myalina Hausmanni, Goldfuss, Petrefacten, part 2, p. 168.
Syns. *Mytilus squamosus* and *M. acuminatus*, J. de C. Sowerby; and *Mytilus septifer*, King.

Generally about half-an-inch long, rarely an inch. Not very common. Occurs both in the Lower Limestone and the Brotherton Beds, being much dwarfed in the latter.

Loc. Lower Limestone; Bull Hill Quarry near Pontefract, Hampole Stubbs, Barnborough Cliff, near Sprotborough, Conisborough, Brodsworth, and Moorhouse. Brotherton Beds; Hampole Quarries*, Knottingley, and Loversall.

4. Myoconcha costata, Brown, Trans. Manch. Geol. Soc., vol. i. p. 32, pl. 6, figs. 34, 35.

Specimens of this species are not rare. They never exceed $\frac{3}{4}$ths of an inch in length, have generally rather convex valves, slightly curved dorsal and ventral margins, with well-marked posterior ribs, and the surface covered with strong lines of growth.

Loc. Brodsworth, Hampole Stubbs, near Barnborough Cliff, Moorhouse, Hampole, and Bull Hill near Pontefract, all in Lower Limestone.

5. Cardiomorpha Pallasi, De Verneuil, Geol. Russ., vol. ii. p. 316.
Syn. *C. modioliformis*, King.

A single right valve of this species occurred in the Lower Limestone at Brodsworth. It is $\frac{2}{5}$ths of an inch long, is strongly angulated, has its umbone depressed, and appears to have had a very thin shell.

* "Hampole Quarries" is the name on the map of the Ordnance Survey for the quarries on each side of the Great North Road, a little to the north of the Holmeroyd Bridge and a mile to the east of Hampole village, and rather more than a mile to the east of the old quarry of Lower Limestone so often mentioned in this paper as the locality of "Hampole."

6. Axinus dubius, Schlotheim, Denksch. Akad. Münch., vol. vi. p. 31, pl. 6. figs. 4, 5. Pl. VII. figs. 11 and 12.

Syns. *Ax. obscurus*, Sowerby; *Ax. parvus*, *pusillus*, *productus*, *undatus*, *elongatus*, *rotundatus*, and *Lucina minima*, Brown; *Schizodus Schlotheimi*, Geinitz; and *Sch. truncatus*, King.

The most common form of this species in Yorkshire is that which has been described by Sowerby under the specific name of "*obscurus*." Its distinguishing features being already so well known, it will be unnecessary to notice them in detail. It differs from other varietal forms of this species in its greater depth anteriorly and in its greater posterior production, in the convexity of its umbonal region and larger umbone, in the obliquity of its hinge-line, and (generally) in the thickness of its shell.

Specimens from some localities—especially those from Moorhouse—show several deep furrows and ridges in the concavity of the umbonal region, running somewhat radiately from the umbone, which are probably visceral markings. Such examples also generally show traces of the muscular impressions. These internal markings are, of course, best seen in specimens with thick shells, and are very faint or not at all perceptible when the shell has not been of moderate thickness, as at Emsall and Brodsworth. The thickness of the shell has been quoted as a specific character by those who consider "*obscurus*" a distinct species; but it may be pointed out that, though the shell of the Yorkshire *Axini* is usually much thicker than the shell of those occurring in Durham, yet its thickness is subject to variation, just as the size of the shell is variable. Some individuals, and those not young ones, have the shell little or no thicker than that of the "*truncatus*" variety of the Shell-limestone of Durham, whereas in other cases the shell is fully three times as thick. Thus, instead of the difference in shell-thickness being of specific value, it would seem to be merely a difference of individual growth, due probably to age and locality, which are known to effect analogous results with the shells of recent Mollusca.

It would appear that *Ax. dubius* attained its maximum development in the British area in the sea of the Lower Limestone. It was there of greater size, more robust, and more prolific than at any other period of its history. In no other district, and on no other horizon, in Yorkshire, Durham, or any other part of Britain where Permian strata occur, does it ever again attain the same size and abundance. During the same period—while the Compact Limestone was accumulating—it was a rare species in the Durham area. And this is a fact worthy of attention: for the two regions are only some eighty miles distant; yet in one it is the commonest species, and in the other amongst the rarest.

The *Axini* of the Brotherton Beds also belong to the "*obscurus*" type; but they are there much dwarfed in size, seldom exceeding half-an-inch in width.

In some localities another variety of this species occurs (figs. 11, 12), which is much smaller than the preceding, its width being only $\frac{6}{10}$ths of an inch. It is almost ovate in marginal outline, is regularly rounded anteriorly, and is a little more produced in that direction than "*obscurus*" or any of the other varieties. Its umbone is comparatively small, and does not extend much above the hinge-line; the hinge-line slopes gently inwards, and its ventral margin is regularly rounded and likewise slopes inwards to the posterior extremity. The valves are regularly convex, and the shell is comparatively thin.

This pretty form of *Ax. dubius* is somewhat rare, and has only occurred to me in Lower Limestone at Conisborough, Hampole Stubbs, and Brodsworth.

Loc. In the Lower Limestone at Bull Hill Quarry and other localities about Pontefract, at Wentbridge, Hampole, Hampole Stubbs, Moorhouse, Pickburn, Brodsworth, Conisborough, Hooton Pagnell, Emsall, and Barnborough Cliff; on Prof. King's authority it likewise occurs at Garforth Cliff, Woodhall, and Nosterfield.—In Upper Limestone at Knottingley, Loversall, Wadworth, and south of Robin Hood's Well.

7. Macrodon striatus, Schlotheim, Denksch. Akad. Münch., vol. vi. p. 31, pl. 6. fig. 3.

Syns. *Cucullæa sulcata*, Phillips*; *Arca tumida*, J. Sowerby; *A. antiqua*, Münster; *A. Loftusiana*, Howse; *A. Kingiana*, De Verneuil.

Three separate valves of this species have occurred to me in the Lower Limestone. Their size is very small compared with Durham examples, being apparently of stunted growth. The largest is half-an-inch in width.

Loc. Moorhouse, and Holywell Hill (Conisborough).

8. Leda speluncaria, Geinitz, Versteinerungen Zech., p. 9, pl. 4. fig. 6.

Syn. *Leda Vinti*, King.

I possess two specimens of this interesting species from the Lower Limestone of Moorhouse. One is a good cast of a right valve with a portion of the shell adhering to one extremity; the other is a bad cast of a left valve. The former is about $\frac{5}{8}$ths of an inch in width, and differs little from Durham specimens, except in being rather more acuminate posteriorly, and in having the umbonal ridge much broader and stronger than they.

Brachiopoda.

1. Terebratula elongata, Schlotheim, Denksch. Akad. Münch., vol. vi. p. 27, pl. 7. fig. 7.

Syns. *T. sufflata*, *complanata*, *lata*, *communis*, and *intermedia*, Schlotheim.

Both the typical form of this species and the variety *sufflata* occur in the Lower Limestone, the individuals of both varying in relative length and width in different localities, but never attaining so large a size as in Durham. My largest specimen is half an inch long,

* This is probably the shell noticed by Prof. Phillips, under the name of *Cucullæa*, as occurring in the neighbourhood of Ferry Bridge. See Phil. Mag., new series, 1828, p. 401.

which is an uncommon length. It is not a rare species at Conisborough, where the individuals belong to the typical form; nor at Hampole, where individuals of both forms occur, though exceedingly stunted even for Yorkshire.

T. elongata is the only Brachiopod that has been found in the Permian series of South Yorkshire.

Loc. In Lower Limestone at Conisborough, Brodsworth, Hampole, Hampole Stubbs, and near Wentbridge. It has also been noticed by Prof. Phillips in the vicinity of Ferry Bridge.

Polyzoa.

1. Acanthocladia anceps, Schlotheim, Denksch. Akad. Münch., vol. vi. p. 20, pl. 2. fig. 7.

A. anceps is the common *Polyzoon* of the Permian strata of this district. It here takes the place—and more than takes it—of the *Fenestella retiformis* of the Durham beds. It is usually, however, much broken up, good characteristic specimens being rare. In only one quarry (Freestone Quarry) near Brodsworth, have I met with illustrative examples showing the symmetrical branching of the stems, and more rarely the celluliferous surface.

Both in the quarry named and in others at Cadeby and Hampole, the remains of this species form almost the chief bulk of thick beds of limestone that have long been wrought as a building-stone in the district a little west of Doncaster. The remains of *Acanthocladiæ* are to be seen studding the surfaces of the weatherworn walls of the ancient stone buildings of this district. When at Conisborough I saw it in company with *Gervillia antiqua* in the stones of the walls of the castle-keep—probably old acquaintances of Athelstan the Unready and his compatriots in 'Ivanhoe'!

Loc. In Lower Limestone at Brodsworth, Pickburn, Hampole, Hampole Stubbs, Bull Hill Quarry (Pontefract), and Conisborough.

2. Thamniscus dubius, Schlotheim, Petrefacten, p. 341.

Syn. *Fenestella ramosa*, King.

I have taken a specimen of a *Polyzoon* which very much resembles this species. It is rather above an inch long, shows the unceIluliferous face, and has a principal stem about $\frac{1}{25}$th of an inch in width, with many irregular branches almost as wide.

Loc. Freestone Quarry, Brodsworth.

3. Retepora Ehrenbergi, Geinitz, Grundriss der Versteinerung., p. 585, pl. 23. fig. 12.

Syn. *R. Lonsdalii*, Howse; *Fenestella Permiana*, King.

Interesting fragments of this scarce species occur, along with the two preceding, in the Freestone Quarry at Brodsworth.

4. Stenopora Mackrothi, Geinitz, Grundriss der Versteinerung., p. 582.

Small specimens of simple and branched stems of this species occur among the débris of *Acanthocladia anceps*. In the Brodsworth Freestone Quarry the examples are always sections, some of which show the internal arrangement of the cells very clearly. At Hampole

I have taken it in minute globose and egg-shaped masses, one of which has a spine-like body for an axis.

Loc. Lower Limestone; Freestone Quarry, Brodsworth, and Hampole.

ENTOMOSTRACA.

1. CYTHERE (BAIRDIA) PLEBEIA, Reuss, Jahresbericht der Wetterau. Gesell. 1854, p. 67.

Syn. *C.* (*Bairdia*) *curta*, Jones (not McCoy).

Several specimens of this species have occurred in the Lower Limestone at Hampole, and amongst them the varieties *elongata*, *Neptuni*, and *compressa*. Also a single specimen of the variety *ventricosa* at the neighbouring locality of Moorhouse.

2. CYTHERE (BAIRDIA) SCHAUROTHIANA, Kirkby, Ann. & Mag. Nat. Hist., ser. 3. vol. ii. p. 329, pl. 10. f. 14; and Trans. Tynes. Nat. Field-club, vol. iv. p. 147, pl. 9. f. 14.

A single specimen of this species occurred at Hampole.

3. CYTHERE (BAIRDIA) AMPLA, Reuss, Jahresb. Wetter. Ges. 1854, p. 68, f. 7 *a*, 7 *b*.

A fine example of this species occurred to me in the Lower Limestone at Hampole, and has been noticed and figured by Mr. Jones in the Transactions of the Tyneside Naturalists' Field-club (vol. iv. p. 166, pl. 11. figs. 19 *a*, 19 *f*).

Its only other locality in England is in the Upper Limestone of Durham at Byers' Quarry, where it is a rare fossil.

4. CYTHERE (CYTHERIDEIS) JONESIANA, Kirkby, Ann. & Mag. Nat. Hist., ser. 3. vol. ii. p. 432, pl. 11. figs. 1, 2; and Trans. Tyne. Nat. Field-club, vol. iv. p. 151, pl. 11. figs. 24, 25.

Syn. *Bairdia gracilis*, Reuss (not McCoy).

Occurs rarely at Hampole.

5. KIRKBYA PERMIANA, Jones, Monog. Perm. Foss. of England, p. 66. pl. 18. fig. 1; and Trans. Tyne. Nat. Field-club, vol. iv. p. 129, pl. 8 *a*. figs. 1–9.

I have only met with this species once at Hampole. The specimen found agrees in size and general character with those of the Shell-limestone of Durham; the sculpture of the valves is well marked.

The specimens of *Entomostraca* which I have obtained at Hampole are pretty well preserved, and are generally perfect carapaces*. One of the beds at this locality is very friable, and decays rapidly by the action of the weather; and it is in the débris thus formed that I have found most of my Yorkshire examples of this class.

FORAMINIFERA.

1. MILIOLA PUSILLA, Geinitz, Sp. Verstein. Zechstein. und Roth., p. 6, pl. 3. figs. 3–6.

Rather common at Hampole along with the *Entomostraca*. In

* The locality of Hampole is so often mentioned in this memoir, and is so well worthy of further search, that I may remark that it refers to a little old quarry by the side of the road leading from Doncaster to Wakefield, a short distance to the west of the village, and not far from the Swan Inn.

most cases oval-shaped and flat; the coils approximating more or less to a regular arrangement on one plane, as in *Spirillina*. Rarely disk-shaped, simulating (?) the *Spirillina*. Occasionally more globose or cylindrical in form,—the coils overlapping irregularly, as generally occurs in Durham examples. The coils are also narrower, and the general habit of the specimens less robust than in Durham examples.

Usual size: $\frac{1}{20}$th in. long, $\frac{1}{30}$th in. greatest width, $\frac{1}{60}$ in. least width; largest specimens, $\frac{1}{15}$th in. long, $\frac{1}{18}$th in. greatest width, $\frac{1}{40}$th in. least width.

In Yorkshire it only occurs at Hampole. It is not rare in the Shell-limestone of Durham, nor in the Unter Zechstein of Germany.

ALGÆ.

The surfaces of slabs in the Brotherton Beds are often covered with the remains of an obscure fossil which probably belongs to the *Algæ*. The fragments are filiform, linear or slightly curved, cylindrical or rather compressed, rarely branched, about an inch in length when longest, but generally shorter, and about $\frac{1}{40}$th of an inch or less in breadth. They are often of a brown or reddish tinge—the surface of the slabs being grey or yellowish—and stand out in relief. They show no trace of structure; and they not only occur on the surface of the slabs, but in the substance of the beds.

These are often associated with *Axinus dubius*. At Knottingley the fragments are arranged linearly, with their longer axis in one direction, as if by the influence of a current. Indeed the imperfect condition of the specimens, and the manner in which they are scattered over the surface of the slabs, would seem to indicate that they were all more or less subjected to drift-action.

In the Upper Limestone of Durham—the equivalent of the Brotherton Beds—obscure remains of *Algæ* similar to those under notice likewise occur, and they are also associated with the same shell. These remains are in a carbonized state, and are scarcely so much broken up as those of Yorkshire, but they possess much the same character as the latter, and it is not improbable that they may belong to the same species.

The obscure fossils resembling *Serpula* or *Dentalium*, noticed by Prof. Sedgwick in the Brotherton Beds at Cold Hill, near Aberford*, are probably identical with this fossil.

Loc. In Brotherton Beds at Knottingley, Pickburn Leys, and Wadworth.

The occurrence of another fossil, of somewhat obscure affinities, though possibly an Annelid, may here be noticed.

It is a cast of a laterally compressed tube, 3 inches long (neither end being perfect), $\frac{3}{8}$ths of an inch in longest width, and $\frac{7}{30}$ths in shorter width. It is slightly arcuate longitudinally, and has an oval, or rather ovate section transversely—the convex edge being more flatly rounded than the other. Between the cast and the investing matrix there is a slight space, which appears to have been originally occupied by the walls of the tube.

* Trans. Geol. Soc., 2nd ser. vol. iii. p. 118.

A similar fossil has occurred in the Shell- and Compact Limestones of Durham, agreeing in most respects with the one described.

Loc. In Lower Limestone at Hampole Stubbs, and from a roadside stone-heap between Hampole and Hooton Pagnell.

The following table gives a synoptical view of the Permian species of South Yorkshire, and shows their general distribution in the Permian deposits of Britain:—

		Names of Genus, Species, &c.	South Yorkshire.					Durham.							
			Rothliegendes.	Lower Limestone.	Small-grained Dolomite.	Brotherton Beds.	Bunter Schiefer.	Rothliegendes.	Marl-slate.	Compact Limestone.	Shell Limestone.	Upper Limestone.	Bunter Schiefer.	N.W. of England (Lancashire Beds).	Ireland.
1	*	Nautilus Freieslebeni, *Geinitz*	...	*	...	...	...	...	...	*	*				
2	*	Turbo helicinus, *Schloth.* ...	...	*	...	...	...	...	...	...	*	*	...	*	*
3		Rissoa Leighi, *Brown*	...	*	...	...	...	...	...	...	...	...	...	*	*
4		Turritella Altenburgensis, *Geinitz*	...	*	...	...	...	...	...	...	*	...	...	...	*
5		Chemnitzia Roesleri, *Geinitz.*	...	*	...	...	...	...	...	...	*				
6		Straparollus Permianus, *King*	...	*	...	...	...	...	...	...	*				
7		Natica minima? *Brown* ...	...	*	...	...	...	...	...	...	...	...	...	*	
8	*	Chiton Loftusianus, *King* ...	...	*	...	...	...	...	...	...	*				
9	*	Dentalium Sorbyi, *King* ...	...	*	...	...	...	...	. .	...	*				
10	*	Monotis speluncaria, *Schloth.*	..	*	...	...	...	...	...	*	*				
11	*	Gervillia antiqua, *Münst.* ...	...	*	...	...	...	...	...	*	*	...	...	*	*
12	*	—— keratophaga, *Schloth.*	...	*	...	...	...	...	...	...	*				
13	*	Myalina Hausmanni, *Goldf.*	...	*	...	*	...	...	*	...	*	*	...	...	*
14		Myoconcha costata, *Brown.*	...	*	...	...	...	...	...	*	*	*	...	*	*
15	*	Macrodon striatus, *Schloth.*	...	*	...	...	...	...	...	...	*				
16		Leda speluncaria, *Geinitz* ...	...	*	...	...	...	...	...	*	*	*			
17	*	Axinus dubius, *Schloth.* var. obscurus, *Sow.*	...	*	...	*	...	...	...	*	*	*	...	*	*
		—— ——, ——, new variety	...	*											
18		Cardiomorpha Pallasi, *De Vern.*	...	*	...	...	...	...	...	...	*				
19	*	Terebratula elongata, *Schloth*	..	*	...	...	...	...	...	*	*				
20		Acanthocladia anceps, *Schloth*	...	*	...	...	...	...	...	*	*				
21		Thamniscus dubius, *Schloth.*	...	*	...	...	...	...	...	...	*	...	...	...	*
22		Retepora Ehrenbergi, *Geinitz*	...	*	...	...	...	...	...	*	*				
23		Stenopora Mackrothi, *Geinitz*	...	*	...	...	...	...	...	*	*	...	...	...	*
24		Cythere (Bairdia) plebeia, *Reuss*	...	*	...	...	...	...	...	...	*	*			
25		—— —— Schaurothiana, *Kirkby*.........................	...	*	...	...	...	...	..	...	*				
26		—— —— ampla, *Reuss.* ...	...	*	...	...	...	...	...	...	...	*			
27		——(Cytherideis) Jonesiana, *Kirkby*	...	*	...	...	...	...	...	...	*	*			
28		Kirkbya Permiana, *Jones* ...	...	*	...	...	...	...	...	...	*	*			
29		Miliola pusilla, *Geinitz*......	...	*	...	...	...	...	...	*	*	...	...	...	*
30	*	?Sp. undetermined (Alga) ...	...	...	...	*	...	...	...	..	...	*			
31		Sp. undetermined (Tubular fossil)	...	*	...	...	...	...	...	*	*				

Those species with asterisks on their left have been previously noticed by Professors Phillips, Sedgwick, and King, as occurring in Yorkshire.

It is stated by Prof. Sedgwick that *Productus horridus* (or *P. calvus*) was found by him in the "upper thin-bedded limestone" between Nosterfield and Well*. It is very difficult to doubt the observation of Prof. Sedgwick; but I can scarcely help doing so in the present instance when I consider the utter absence of Brachiopods in *all* the Upper Permian Beds, not only of England, but of Western Europe generally.

§ V. *Distribution of the Fossils.*—This list of fossils contains all that are yet known to occur in the Permian rocks of South Yorkshire. Without including the localities searched by Profs. Sedgwick and Phillips, it represents the result of an examination of not less than twenty fossiliferous localities visited by myself. If we add to these the localities examined by the geologists named, and not visited by me, and consider that they only met with one species which I have not found, I think we may almost conclude that the list given takes in most, if not all, of the common fossils of the district. Nevertheless it is not to be doubted that a more continued search would add to the number of species, and improve our knowledge of them generally.

It will be apparent enough from this list that fossils are only found in two subdivisions—in the Lower Limestone and the Brotherton Beds. And it will be just as apparent that nearly all the species are confined to the Lower Limestone, only three occurring in the Brotherton Beds. What we know, therefore, of the fossils of the Permian rocks of this district is in the main derived from a single subdivision belonging to the inferior half of the series.

A. *Fossils of the Lower Limestone.*—In the Lower Limestone the best localities for fossils are in the oolitic, and what I have termed the polyzoan beds. Fossils are found throughout the whole of the various beds of this member, but are most plentiful, both in species and individuals, in the beds mentioned. They are not, however, well preserved, being in most cases casts merely, those of Hampole being the chief exception. The best localities—those most rich in species and individuals, and where the latter are most finely developed and best preserved—that I had the opportunity of examining are the old quarries at Hampole, Hampole Stubbs, and Moorhouse, the Freestone Quarry near Brodsworth, and the Holywell Hill Quarries at Conisborough; all of which would certainly repay further examination, and particularly the continued researches of a local geologist. In all localities the *Conchifera* are generally found in single valves. This holds good with every species of this class†. The *Polyzoa* too are

* Trans. Geol. Soc., 2nd ser. vol. iii. p. 108.

† The dislocation of the valves of fossil *Conchifera* does not necessarily imply that they were subjected to the action of currents, and probably transported from distant regions prior to their being imbedded in sediment and fossilized. In most cases when a Conchifer dies and its adductor muscles relax, the valves of its shell spring open more or less by the elasticity of the ligament. And should the valves thus remain for a moderate length of time uncovered by sediment, the ligament and fleshy portion of the Mollusk decay, or are otherwise removed, and

always more or less fragmentary. The *Gasteropoda* seem to have suffered no injury prior to inhumation. In several places the specimens, even as casts, are so badly preserved as scarcely to be determinable. This appears to result from two causes,—sometimes being apparently the fault of the investing matrix, whose preservative qualities have been poor; and at others it is owing to the distortion of the specimens by compression during the process of fossilization. The most remarkable instance of the latter kind that I have met with is near to Hampole Stubbs, where there is a bed of compact brown limestone full of *Axini* pressed flat, and, in consequence, broken into many pieces. I observed another example of this kind at Conisborough, where *Terebratula elongata*, which is not a rare shell there, and of rather large size for Yorkshire, is almost invariably more or less distorted by pressure, while the shells of other species—Gasteropods and Conchifers—are scarcely ever similarly affected. In this case the *Terebratulæ* must have been less able to resist the amount of pressure to which the organic remains of this locality were subjected than their associates. And perhaps this may be explained, in the first place, by their much thinner shell, and in the second, because of their having been imbedded with closed valves, their dental system not allowing the easy opening or dislocation of the valves after the death of the Mollusk, which would thus prevent the entrance of sediment into the cavity of the shell, to the great disadvantage of the valves resisting the pressure of the gradually increasing superincumbent mass.

Moorhouse.—One of the most interesting localities is an old quarry near to the hamlet of Moorhouse, where *Axinus dubius* occurs in great profusion, and most finely developed, both in respect to size, thickness of shell, and general character. Its peculiar umbonal ridges are very finely displayed in the casts of this locality. Several other species likewise occur, and amongst them some of the rarest of the Yorkshire forms. The limestone is oolitic; and there is one bed in particular which contains the fossils most abundantly; its position is only seven or eight feet above the Lower Red Sandstone, which is exposed in the same quarry.

Hampole.—About half a mile to the east of the preceding locality is another old quarry, of very ignoble appearance, at Hampole, where there are some beds of fossiliferous limestone apparently situated a little above the oolitic beds of Moorhouse. From this spot I have obtained seventeen species, and many of them are immature and somewhat dwarfed. *Axinus dubius*, which is so large at Moorhouse, is here never more than half-an-inch in width. And *Turbo helicinus*, which

all connexion between the valves ceases, in which state they would subsequently be imbedded, were a deposition of sediment to take place before the decay of the valves themselves. It is extremely probable that this is one of the causes of the valves of fossil *Conchifera* so often occurring detached. When shells of this class are found fossilized with their valves closed and in perfect juxtaposition, it is natural to suppose that their ligament was slight and of little strength, or that they were burrowers, or, at least, if not burrowers, that they had been enveloped in sediment while living; so that, on the relaxation of the adductor muscles from death, the valves would be kept closed by the external pressure of the surrounding sediment.

is the common fossil of the locality, is only one-fourth its usual size. The molluscan remains are mixed with comminuted *Polyzoa*, chiefly of the species *Acan. anceps*, the fragments being very small, though numerous. As it happens, however, the reduction in size of the fossils is accompanied by an improvement in their state of preservation, and particularly in respect to the Univalves, which are generally testiferous. So numerous are these minute fossils in some parts of the quarry, that the quantity of them that occur in a small portion of matrix is most surprising, a fact rendered easy of proof by the friable nature of the matrix. As illustrative of this, I may mention that in but a quarter of an ounce of limestone I have picked out 298 separate organisms, the majority being specimens of *Turbo helicinus*. Another experiment of a like kind, the quantity of limestone being the same, yielded even more astonishing results. From it I extracted 461 specimens of *T. helicinus*, 18 of *Turrit. Altenburgensis*, 7 of *Ris. Leighi*, 2 of *Terebrat. elongata*, 1 of *Bairdia plebeia*, 24 of *Miliola pusilla*, and 8 fragments of *Stenopora Mackrothi*; in all 513 organisms. A cubic foot of this limestone of equal richness as the latter throughout, and supposing it to weigh 120 lbs. (a low estimate), would contain very nearly 4,000,000 of distinct individuals—and these not truly microscopic, but distinguishable with the naked eye, most of them being Gasteropodous *Mollusca*. All the limestone of this locality, however, is not so highly fossiliferous as in these examples, there apparently being certain zones of limestone that are pre-eminently fossiliferous. Besides illustrating the extreme abundance of these minute fossils, the above facts give a good idea of the relative abundance of individuals belonging to the different species. They show that *Turbo helicinus* is by far the most common form, and that its individuals outnumber many times over the aggregate of those of all the other species. And this is the only instance I have met with where the Gasteropod in question, though very generally distributed in the Lower Limestone, has taken the leading place among the fossils of a locality. And, besides, this is the only locality in Yorkshire—perhaps in England—where *Gasteropoda* hold so important a position in the list of species, about half of the *Mollusca* being species of this class.

Near Brodsworth.—Another interesting locality is near to Brodsworth in some old quarries just to the west of the village, where the beds belong to the higher part of the Lower Limestone. The predominating fossil here is *Gervillia antiqua*, its casts composing almost the whole of the substance of some of the beds. This species is just as common here as *Axinus dubius* is at Moorhouse, or *Turbo helicinus* at Hampole. And the beds in which it is so plentiful are probably identical with those at Wentbridge, Pontefract, etc., where we have noticed it as occurring in similar profusion. Along with the *Gervilliœ* are to be found the remains of a few other species, amongst which (rarely) are those of *Nautilus Freieslebeni* and *Chiton Loftusianus*.

Near Pickburn.—Between Pickburn and Marr there is a quarry called by the villagers the "Freestone Quarry*"—of thick-bedded

* In the south of Yorkshire any stone that can be easily worked by the mason is termed a "freestone." In Durham this term is only applied to sandstones.

oolitic and polyzoan limestone, from which I obtained an interesting suite of fossils. The common fossil is a *Polyzoon—Acanthocladia anceps.* The associated species, among which are those mentioned as the common fossils of other localities, are all of subordinate importance in respect to individual distribution. Besides the species of *Polyzoa* named, three others have occurred to me in the polyzoan beds, two of which (*Retepora Ehrenbergi* and *Thamniscus dubius*) are peculiar to it. The beds in which the *Polyzoa* are so profusely distributed scarcely ever contain species belonging to other classes.

I chiefly notice these fossiliferous localities in detail to draw some attention to the manner in which different species characterize certain localities. In some cases this seems to be due to the localities representing different horizons of the Lower Limestone, consequently different periods of Permian time, which in this area were characterized by the prevalence of different common species. This is certainly the case with the Moorhouse and Brodsworth localities, whose vertical position in the series it is not difficult to test, the former evidently underlying the latter. In other instances the differences observed appear to be merely those of geographical distribution; as, for example, that of Hampole and the Freestone Quarry near Pickburn, the beds of both appearing to be of the same relative position. To the palæontologist these groups of species and their differences are of particular importance—just as much, perhaps, as the larger groups (and their differences) belonging to different formations of strata: for, as the one tells of great and wide-spread changes in the relations of ancient life during the elapse of immense ages, so does the other of the small and limited changes which happened during shorter periods, and from which the first eventuate.

The species that are found furthest down in the Lower Limestone are *Axinus dubius* and *Gervillia antiqua.* Casts of these shells (those of the former being most prevalent) occur in the lowest beds of compact and earthy limestones immediately above the Rothliegendes at Carlton, Wentbridge, and Pontefract (Bagg Hill). Other species soon appear in the beds that follow; but for some feet upwards *Axinus dubius* holds its own, and increases in size and numbers, until it attains its maximum in certain strata, not so very far above the sandstone as at Moorhouse and Conisborough. In the succeeding beds *Gervillia antiqua* becomes very numerous and takes the place of the other as common species. Near about the same horizon as the latter, or possibly a little below it, are the beds in which *Acanthocladia anceps* is so common in the region between the Don and the Went. Above these beds and in the highest portion of the member, fossils become rarer, and the species that occur are more equally represented.

The assemblage of fossils at Hampole is, perhaps, the most curious of any that occurred to me in South Yorkshire. As already remarked, it is chiefly composed of Univalves, all of which are minute, their small size being due in the case of *Turbo helicinus*, *Turritella Altenburgensis*, and one or two others, to the immature condition of the specimens, which are invariably young and somewhat dwarfed individuals. The associated specimens of *Rissoa Leighi*, *Natica minima*, and *Straparollus Permianus* are mature individuals, so far as the development of these species is known to us from their occurrence in the Permian strata of other districts. The latter, however, are smaller species than the former, and their individuals are of about similar gravities as the immature examples of the first-named species. Hence when we consider their great numbers, smallness, and general uniformity of size, and the comminuted state of the *Polyzoa* that occur along with them, it seems likely that we have here an instance of the accumulating action of currents. It is easy to understand how a submarine current of a certain power, passing over a sea-bottom strewed with various forms of marine life, could sweep away those organisms whose specific gravities it could overcome to some region more or less distant, where its force became spent or lessened, and there deposit them in quantities as countless as those of Hampole. If its power never exceeded a certain limit, the larger and more weighty organisms would not be removed, while the smaller, if unattached and not otherwise held down, would be carried off; and supposing the currents were periodical and occurring only at stated seasons, hosts of young shells at a particular stage of development might be swept away at intervals. It must certainly be allowed that the fossils individually show no perceptible traces of such a removal, though to what extent traces of this kind in the shape of abrasion, etc., would be perceptible in the case of transportation over a soft sea-bottom, such as the Lower Limestone in the course of deposition would surely form, does not appear, though we can readily conceive that they would possibly not be very evident. There may be other ways of accounting for the aggregation of so many minute Univalves in one locality; but I certainly know of none that so well explains the facts of the case as the one suggested. Nor do I know of any other instance in the Permian deposits of Yorkshire and Durham, where we seem to have such indications of the influence of ancient submarine currents in the distribution or rather accumulation of their organic remains.

The polyzoan beds also seem to be at first sight an accumulation of drifted materials. This is only a natural surmise on finding so fragmentary an assemblage of remains as those which enter so largely into the composition of these strata. Nevertheless I am disposed to consider them the remains of *Polyzoa* that lived where we find them, and that the range of the beds marks the site of an ancient ground or zone altogether (or nearly so) peopled by *Polyzoa*,—where they lived and died generation after generation for a long period, the latter generations growing on a sea-bottom composed of fragments of the polypidoms that preceded them, until at last, owing to reasons unknown, their growth ceased after the accumulation of several thick beds of their remains. This I think is proved by the fossils belonging nearly altogether to *Polyzoa*. Had they been accumulated by the action of a current sweeping over the bottom of the sea, there would surely be observed amongst them a greater mixture of other species, more especially as we know that there were several others which helped to people the sea-bottom of the South Yorkshire region during the aggregation of the beds.

B. *Fossils of the Brotherton Beds.*—Little can be said relative to any peculiarities in the distribution of fossils in the Brotherton Beds. The chief feature is most certainly their great paucity both specifically and individually. The three species which occur in them are generally associated; when any one of them is found alone, it is *Axinus dubius.* Their occurrence is not general throughout the vertical thickness of the beds, there being many of the strata quite unfossiliferous. They characterize certain strata, and on the upper surfaces of these they are often rather thickly strewed. The size of the two Conchifers which occur is greatly reduced in the Brotherton Beds, more particularly in the case of *Ax. dubius.* Here it never exceeds half-an-inch in width, while in the Lower Limestone it is at times fully two inches. It also shows slight modifications of form, approaching in outline the variety *Schlotheimi* of Geinitz, though somewhat intermediate between it and *obscurus.* The only species peculiar to these beds is the *Alga* already noticed.

§ VI. *Permian Fossils of South Yorkshire compared with those of Durham.*—An examination of the preceding table shows that all the species, with the exception of two, occur in the Permian beds of Durham; and both of these are found in the Lancashire beds. It is thus seen that none are peculiar to South Yorkshire. It is also evident that most of the species are not confined to the British area, several being among the most sporadic of Permian species. Out of the 31 species 25 are common to Germany and Britain, most of which existed in the former region at the period of the Lower Limestone. Ten species are common to Russia and Germany, and a less number (4) to Russia, Germany, and the Permian strata of North America. The *Conchifera*, along with the Cephalopod and the Brachiopod, are all extra-British; two-thirds of the former and each of the representatives of the latter classes range through Germany into Russia. All the *Polyzoa* are German; but none are Russian. The *Entomostraca*, with one exception (*Bairdia Schaurothiana*), are German, one (*Kirkbya Permiana*) having also Russian varieties. The Rhizopod is a Zechstein species. The species most confined in their range are Gasteropods. Of the members of this class only one is Russian, 5 are German, and 3 are peculiar to Britain. In all, 5 species appear to be confined to the British area.

Compared with the Permian fauna of Durham—taking it at its maximum development during the deposition of the Shell-limestone —the group of species found in the Lower Limestone forms but a meagre life-group so far as number of species is concerned. The number of species composing the former is 118, while of the latter there are only 31. This does not, however, prove a rarity of life in the Yorkshire area; for the fewness of species seems to have been counterbalanced in some degree by a greater individual abundance, —the remains of *Gervilliæ* at Wentbridge, &c., and of *Turbo helicinus* at Hampole, exceeding anything of the kind to be observed in the most fossiliferous localities of Durham. The chief differences are absences, that of Brachiopoda being the most notable. In the most fossiliferous localities in Durham, Brachiopods are the commonest fossils. In Yorkshire the only species of this class that occurs is almost among the rarest. The two common Polyzoans of Durham—*Fenestella retiformis* and *Synocladia virgulacea*—are also wanting, their places being apparently taken by *Acanthocladia anceps*. The common Echinoderm of Durham is absent, as are also other species too numerous to name, several of which are common forms in the Durham beds. On the other hand, *Nautilus Freieslebeni*, *Chemnitzia Roessleri*, *Straparollus Permianus*, *Chiton Loftusianus*, *Monotis speluncaria*, *Macrodon striatus*, *Terebratula elongata*, *Acanthocladia anceps*, *Retepora Ehrenbergi*, *Miliola pusilla*, as well as others that are common to both faunæ, and which in Durham and Germany are confined to the lower and middle subdivisions, form a most intimate relationship between the two, and afford strong palæontological evidence—were any wanting—of the inferior position in the series of the deposits containing the Yorkshire group of species.

But to form a just comparison with the Durham fauna, we must take it as developed during the deposition of the Compact Limestone, the equivalent—in great measure—of the Lower Limestone. But before doing this, it may again be pointed out that the fossils of the Compact Limestone do not represent the earliest traces of Permian life in Durham, as do those of the Lower Limestone in Yorkshire. In the latter county the deposition of the Lower Red Sandstone or Rothliegendes was immediately followed by that of the Lower Limestone; at least there was no intermediate deposition. In Durham a deposit of semicalcareous, semiargillaceous sediment followed that of the Rothliegendes, and preceded that of the Compact Limestone—thus separating the two deposits by a few feet of calcareous shale, which has been named the Marl-slate. It was during the deposition of this shale that animal life may be said to have first appeared in the Durham area during Permian time,—*Lingula Credneri*, *Discina Konincki*, and *Myalina Hausmanni*, with several Fishes, forming this *avant-garde* of the larger fauna that afterwards peopled the same area. I have little doubt that these species were contemporaries with those of the fauna of the Lower Limestone, though only for a season; for on the commencement of deposition of the Compact Limestone, another set of species gradually took their place, and became in turn contemporaries of the same Yorkshire species, which continued to people the Yorkshire area while the changes noticed were occurring in Durham. And it was not until the era of the Compact Limestone that the physical conditions of the Durham area became analogous to those prevailing in the area of Yorkshire, and that the distribution of species therein became, like those of Yorkshire, of an unquestionably marine character. It is, therefore, chiefly with them that we have to do in comparing the contemporary faunæ of the two districts.

As far as we are acquainted with the fossils of the Compact Limestone, they amount to 31 species, thus forming a group of equal number with those of the Lower Limestone. A list of these species is given in the following table, the *Mollusca* and *Polyzoa* of the Lower Limestone being placed in juxtaposition for the sake of easy comparison:—

Compact Limestone (Durham).	*Lower Limestone (South Yorkshire)*.*
Dentalina Permiana.	
Miliola pusilla.	
Kirkbya Permiana.	* K. Permiana.
Retepora Ehrenbergi.	* Retepora Ehrenbergi.
Acanthocladia anceps.	* Acanthocladia anceps.
Fenestella retiformis.	
Stenopora Mackrothi,	* Stenopora Mackrothi.
Synocladia virgulacea.	
	Thamniscus dubius.
Lingula Credneri.	
Discina Konincki.	
Productus horridus.	
Strophalosia lamellosa.	
——— Goldfussi.	
Streptorhynchus pelargonatus.	
Spirifera alata.	
Camarophoria crumena.	
——— globulina.	
Spirifera Urii.	
Terebratula elongata.	* Terebratula elongata.
Monotis speluncaria.	* Monotis speluncaria.
Gervillia antiqua.	* Gervillia antiqua.
	* ——— keratophaga.
Axinus dubius.	* Axinus dubius.
Myoconcha costata.	* Myoconcha costata.
Leda speluncaria.	* Leda speluncaria.
Astarte Vallisnieriana.	
——— Tunstallensis.	
Solemya biarmica.	
——— normalis.	
Pecten pusillus.	
Myacites lunulata.	
	Myalina Hausmanni.
	* Cardiomorpha Pallasi.
Pleurotomaria Verneuili.	* Macrodon striatus.
	Turbo helicinus.
	Rissoa Leighi.
	Turrit. Altenburgensis.
	* Chemnitzia Roessleri.
	Natica minima.
	Chiton Loftusianus.
	* Dentalium Sorbyi.
	* Straparollus Permianus.
Nautilus Freieslebeni.	* Nautilus Freieslebeni.
† Platysomus striatus.	

It is thus seen that 11 species are common to both groups, amongst which are the Cephalopod, 5 Conchifers, the Brachiopod, 3 Polyzoans, and 1 Entomostracan. When we consider the nearness of the two areas—their distance apart being only about 80 miles—

* The species marked with asterisks occur in the Zechstein.

† The list of species from the Compact Limestone is based upon the researches of Prof. King, Mr. Howse, Mr. Manson, and Mr. Parker.

so slight an admixture of species is a matter of surprise, particularly when an examination of the fauna of the Unter Zechstein, which appears to have been of contemporaneous deposition with the Compact Limestone of Durham and the Lower Limestone of Yorkshire, shows that 21 of the Yorkshire species (viz. 1 Cephalopod, 3 Gasteropods, 8 Conchifers, 1 Brachiopod, 3 Polyzoans, 4 Entomostracans, and 1 Rhizopod) were distributed in the German area during the same period.

In the Yorkshire fauna 9 of the species are Gasteropods; in that of the Compact Limestone there is only a single member of the same class. In the Compact Limestone fauna 11 of the species are Brachiopods; in the other there is only one. It is in these respects that the two faunæ differ most. Five out of the 9 Yorkshire *Conchifera* occur in the Compact Limestone: among them are the two common species *Ax. dubius* and *Gerv. antiqua*; but neither of these shells is common there. The most common shell of the Compact Limestone is *Productus horridus*. No species is so common as it; *Strophalosia lamellosa*, *Spirifera alata*, and *Camarophoria crumena* being next in the list of common species. *Acanthocladia anceps*, the common Polyzoan of the Lower Limestone, is not rare in the Compact Limestone, but the place of the common Polyzoan is there taken by *Fenestella retiformis*. One of the Yorkshire Entomostraca is found in the Durham subdivision. The Rhizopod *Miliola pusilla* is common to both faunæ, it being accompanied by a *Dentalina* in the Compact Limestone.

In these differences, in two contemporaneous assemblages of Permian species, we have a good illustration of some of the peculiarities that pertained to the distribution of marine life in palæozoic times. It is thus shown that, according to present researches, there is only about one-third of the species of each fauna common to both groups, thus leaving about two-thirds that are peculiar to each. And it may be remarked that, though all the species peculiar to the South Yorkshire assemblage, except two, were afterwards distributed in the Durham area during the Shell-limestone period, it would yet appear that none of those peculiar to the Durham group were ever common to the other. We can scarcely refer these differences to the result of geographical distribution of species, for we cannot but consider that the Permian deposits of Durham and Yorkshire were accumulated in the same sea; so that it would be perfectly unwarrantable to ascribe differences so great in specific distribution to an agency of this kind, when the two regions were so nearly situated and the nature of the sea-bottom the same. To changes belonging to the distribution of species in depth, however, the differences would easily seem referable; it being now well known that great differences obtain in the distribution of marine life as the zone of depth varies, even with short distances. I would therefore refer the differences observed in these local faunæ to a change in the conditions of depth of sea existing in each area, while their respective deposits were accumulating; the difference being in the greater depth of sea over the Durham area than to the southward over the other. It is probable when we acquire a better knowledge of the fossils occurring in the intervening range of Permian strata in the northern half of Yorkshire, that the differences noticed may be found to be the result of gradual changes in the distribution of species. And it is possible that still further south other arrangements of species may obtain that are peculiar to their own localities; just as in the case of the two following local faunæ which, in all probability, had a contemporaneous existence further to the west.

It is worthy of attention that several of the Yorkshire species, which were of contemporaneous existence in Germany, appeared in the British area first in Yorkshire. This is the case with *Chemnitzia Roessleri*, *Dentalium Sorbyi*, *Turbo helicinus*, *Straparollus Permianus*, *Turritella Altenburgensis*, and *Macrodon striatus*, which did not appear in the Durham area until the era of the Shell-limestone. It is not very evident whether in the latter case the migration was from the Yorkshire region or that of Germany; but as other species accompanied these which do not occur in the Lower Limestone of Yorkshire, though common to the Unter Zechstein, it may be presumed that it proceeded from the latter. Indeed, when we remember that the Permian fauna attained its maximum in Germany during the period of the Unter Zechstein*, and in England not until that of the Shell-limestone, it seems highly probable that a general migration of species—or rather of their individuals, the species still continuing in the old area—took place to the westward while the middle portion of the Permian series was being deposited, especially as more than half of the additions to the British fauna during the Shell-limestone period were Unter Zechstein species.

§ VII. *Permian Fossils of South Yorkshire compared with those of Lancashire.*—There is another group of species with which it may be well to institute a comparison. I refer to that belonging to the Permian strata of Lancashire, whose geographical position is nearer to the Yorkshire beds than that of the Compact Limestone, though their vertical position in the series is not so well determined. This little local fauna consists of only seven species; three of these are Gasteropods—viz. *Turbo helicinus* (with var. *Mancuniensis*), *Rissoa Leighi* (with var. *Gibsoni*), and *Natica minima*. The rest, with the exception of a Sponge (*Tragos Binneyi*), are Conchifers—viz. *Gervillia antiqua*, *Axinus dubius*, and *Myoconcha costata*. Now all these species, except the Sponge, occur in Yorkshire; and all of them are common species there, but the one just-named and *Natica minima*. Two of the species we readily recognize as the most common of the Yorkshire fauna. And two of the Univalves (*Natica minima* and *Rissoa Leighi*) are in England only found in the Lancashire and Yorkshire beds.

Therefore making every allowance for the smallness of the Lancashire group of species, there seems to be a much more intimate relationship between it and the Yorkshire fauna (Lower Limestone), than

* See an excellent table of species occurring in the Zechstein of Germany, by Baron von Schauroth, in the Zeitsch. d. Deut. geol. Gesell. 1854, pp. 569, 574.

between the latter and the Durham fauna during the Compact Limestone era. It is certainly difficult to attempt comparisons with so small a group of species, which may or may not give a fair idea of the original distribution of life in that area, though I incline to the former opinion. We see, however, the same ascendency of Gasteropods and Conchifers, and the same rarity of Brachiopods that obtain in the fauna of the Lower Limestone of Yorkshire. And in these respects we might almost argue a similarity of physical conditions prevailing in the two areas. But the absence of *Polyzoa* and the great reduction in the number of species point to a difference as great perhaps as that which existed between the conditions of the Yorkshire and Durham areas. Between the Lancashire and the Durham faunæ, that of Yorkshire holds an intermediate place. Its zone of depth, as already remarked, was apparently not so great as that of the Compact Limestone, though decidedly greater than that of the sea of the Lancashire area. The fauna of the latter appears to have existed on the argillaceous and semicalcareous submarine mud-flats that lay off the coast of a Permian land-area; the Yorkshire fauna certainly existed further away in deeper water and within the limits of regular deposition of calcareous sediment, though still towards the shallower zones of that region; the fauna of the Compact Limestone of Durham seems to have dwelt still further seaward, where the depth was greatest. These conclusions are in perfect harmony with the teachings of a more comprehensive view of the Permian deposits of Britain; for an examination of them leads to the opinion that the sea which covered so much of the British area in Permian times, deepened to the north and east and shallowed to the south and west. This we may easily prove by tracing the Permian strata from the north-east corner of Durham south and westward, noting the gradual change from magnesian-calcareous deposits to others which are argillaceous, arenaceous, and conglomeratic,—these lithological changes being likewise accompanied by analogous changes in the distribution of the remains of organic life, there being at the one extreme (Durham) a deep-sea fauna in calcareous strata, and at the other (Bristol) a conglomerate charged with the remains of Reptiles.

As before stated, the exact horizon of the fossiliferous beds of the Lancashire series has not been determined; nor is it easy to do so. But it may be suggested that, as the beds in question (which are thin limestones and marls) most probably represent the period of greatest depth of sea attained in the Lancashire area in Permian time, being the only calcareous beds of the series, they may easily be of synchronous deposition with the Lower and Compact Limestones, which are considered to be representatives of the same period in their respective areas. This would certainly be the case if the depression of sea-bottom, which originated the increased depth of sea, arrived at its maximum in all parts of the British area at the same time: and, so far as we know, there is nothing that seems to disprove that it did; at least it is much more likely, when we consider the nearness of the Lancashire and Yorkshire areas, that they were affected alike and attained their maximum depth of sea about the same time, than that they were affected differently and attained their maximum depths at widely different periods *. Granting the former, the comparison we have instituted with the Lancashire fauna is attended with some degree of interest; for it then relates to a group of species of contemporaneous existence with that of the Lower Limestone, as in the case of the Compact-limestone group.

I am aware that Prof. King has incidentally suggested that these beds may possibly belong to the highest portion of the Permian series. But, except the weight of his opinion (for which I make every allowance), I see no fact that supports such a view. And besides the argument already offered in favour of a different classification, there is the fact that four of the species (*G. antiqua*, *R. Leighi*, *N. minima*, and *T. Binneyi*) never occur in the higher beds of the Permian series in other parts of England. This might not be of much consequence were the distribution of species at all variable in the upper beds, so that we might expect to meet with species specially characteristic of certain localities; but there is so great a uniformity of distribution in the highest beds of the series—the very reverse of that in the lowest—that the occurrence of species hitherto found only in the inferior strata in beds of uncertain horizons would certainly favour their classification with the lower rather than the upper members of the series.

§ VIII. *Permian Fossils of Ireland.*—But the group of Permian species to which the fauna of the Lower Limestone approaches most closely is that occurring in the magnesian limestone of Cultra and Tullyconnell in Ireland, described by Prof. King†. This group consists of 11 species; and all of them with one exception (*Cythere Tyronica*) are common to the Yorkshire fauna. Among the *Mollusca* are the common forms of the Yorkshire deposit, as *Gerv. antiqua*, *Ax. dubius*, *Myo. costata*, *Myal. Hausmanni*, *T. helicinus*, *Ris. Leighi*, and *Tur. Altenburgensis*; and among the other species there are also *Sten. Mackrothi*, *Th. dubius*, and *Mil. pusilla*. The two assemblages have very much in common, the principal differences being deficiencies. In both instances Conchifers and Gasteropods are the characteristic Mollusks; and in both, these classes are pretty equally balanced. The all but absence of *Brachiopoda* in the one, and their absence in the other, is another point of agreement; and the representation of *Polyzoa*, *Foraminifera*, and *Entomostraca* by species either identical or closely related completes the similitude.

And it is quite possible, in my opinion, that this Irish group of species may likewise have been of contemporaneous existence with the fauna with which I am comparing it. The horizon of the Cultra and Tullyconnell beds is certainly considered to be high in the series by Prof. King, though, with deference to the Professor's opinion, I would again suggest the possibility of a more appropriate classifica-

* I here argue on the usual assumption of calcareous beds being the deposition of deeper sea than those of an argillaceous and arenaceous nature. That there are exceptions to this it would be useless to dispute; but as a general rule it probably holds good.

† Journ. Geol. Soc. of Dublin, vol. vii. p. 73–78.

tion. In referring these beds to the highest member of the Permian series as developed in the North of England, Prof. King relies on their lithological, chemical, and palæontological characters, all of which are stated to offer a remarkably close agreement with the equivalent features of the highest Permian member of the North of England*. Now, in the first place, the lithological evidence of the Upper Limestone of the North of England is of very little value as an aid to classification. In proof of this I would refer to the Brotherton Beds of Yorkshire, which are as different lithologically from the Upper Limestone of Durham as they are from any other Permian limestone whatever, though their relative position and fossil remains indisputably prove them to be of the same general horizon. The lithological characters of the Upper Limestone of Durham are peculiar to that county; and so are those of the Brotherton Beds to the adjoining counties of Yorkshire and Nottingham. Indeed to take the Magnesian-limestone group as a whole, I question whether there is any series of rocks whose lithological characters are so variable and of so little value in the classification of its different parts. And so it is with the chemical composition of the Upper Limestone. Even in Durham alone, analyses of its different beds show as great a variation in the proportion of chief ingredients as do analyses of limestones of different members. Besides, analyses of the underlying members sometimes so nearly agree with those of the upper, as to destroy the worth of all arguments for the identity of age of different beds from their similarity of chemical composition†. And in respect to the fossils, there certainly does not seem to be much reason for considering them as a group characteristic of the upper beds. Out of the 11 species that occur, 6 (viz. *Sten. Mackrothi*, *Th. dubius*, *Gerv. antiqua*, *Tur. Altenburgensis*, *Ris. Leighi*, and *Mil. pusilla*) have never been found higher than the middle subdivision or Shell-limestone of Durham. And, as Prof. King has justly pointed out, the absence of *Polyzoa* among the species occurring in the upper member is one of the peculiar characteristics of its fauna‡. For this reason I must conclude that the occurrence of two species of this class in the Tullyconnell deposit is opposed to its being considered the equivalent of that member. Four of the species—viz. *Ax. dubius*, *Myal. Hausmanni*,

* *Loc. cit.* p. 79.

† I would refer to the following analyses in corroboration of this assertion. The first is one of the Upper Limestone with which Prof. King has identified the Irish deposit; the other is one of the Compact Limestone, the most inferior limestone member.

Upper Limestone, Hartlepool.		*Compact Limestone, Ferry Hill.*	
Carbonate of Lime	54·5	Carbonate of Lime	54·1
—— of Magnesia	44·9	—— of Magnesia	44·7
Oxide of Iron	0·3	Oxide of Iron	0·6
Earthy matter	0·3	Earthy matter	0·6
	100·0		100·0

Greenwell's Mine-engineering, p. 17.

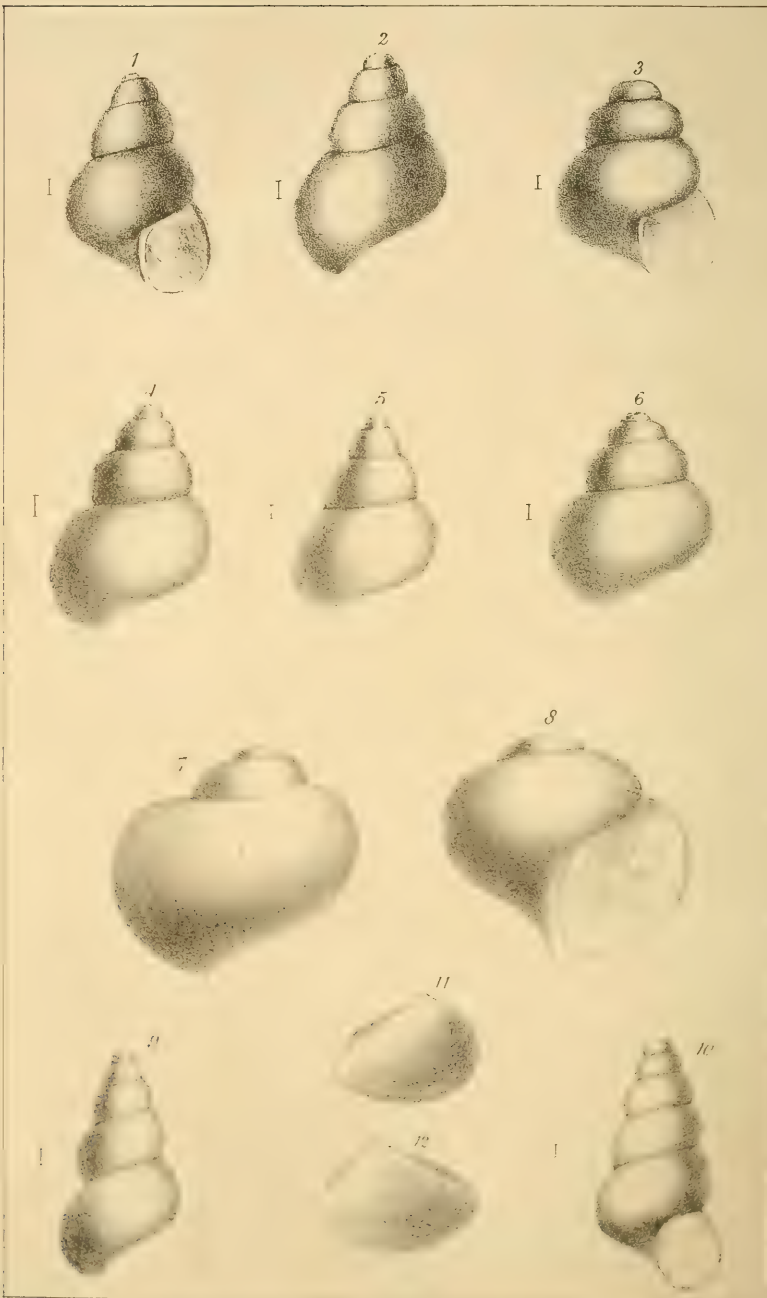
‡ Mon. Perm. Foss. of England, Introduction, pp. xiv, xvi; and paper "On the Occurrence of Permian Magnesian Limestone at Tullyconnell, near Artrea, in the County of Tyrone," Journ. Geol. Soc. of Dublin, vol. vii. p. 60.

Myoch. costata, and *T. helicinus*—are undoubtedly common to the Upper Limestone and the Tullyconnell deposit, though likewise common to the inferior beds; and, had they occurred alone or with other species also characteristic of the higher portion of the series, their evidence would then have been more in favour of Prof. King's suggested classification. But, as they are associated with other species, such as *Sten. Mackrothi*, *Ris. Leighi*, and *Mil. pusilla*, which, in all districts where the succession of beds has been determined, are confined to the lower and middle parts of the series,—and as they are themselves among the most common species of the lower beds in some localities, it would appear pretty certain that the balance of palæontological evidence supports a classification of the Cultra and Tullyconnell beds with the inferior rather than with the superior members of the Permian series.

§ IX. *The Zechstein.*—Time will not allow my attempting comparisons with the groups of species found in the Zechstein of Germany; and to do so would require a wider scope than the limit of this paper permits. Comparisons, however, of this and of the other groups of species found in the Permian strata of Britain with those of the Zechstein would most assuredly bring to light many interesting facts connected with the distribution of marine life, in time and space, during the Permian era. The intimate relation which exists between the marine fossils of the Permian rocks of Britain and Germany proves them to be the remains of one fauna peopling the same geographical province or area of deposition. And to trace the various phases in the history of this fauna, its peculiarities of distribution in space and in time, its development, and manifold relations, will certainly be the work of some palæontologist when our knowledge of it and the strata containing it becomes more advanced.

§ X. *Conclusion. Distribution of the Permian Fauna in Time.*—After the deposition of the Lower Limestone and during that of the Small-grained Dolomite, it would appear as if there had been a total withdrawal of species from the South Yorkshire area. During the same period in Durham the Permian fauna was at its maximum. Thus we have another most remarkable instance of local difference in the geographical distribution of Permian species.

This exodus of species was in most cases permanent. Only two are known to return during the deposition of the Brotherton Beds. Others may certainly be undiscovered; but so far as we know *Axinus dubius* and *Myalina Hausmanni*, accompanied by one, or perhaps two, species of *Algæ* previously unknown, are the only ones that revisit the South Yorkshire area. During the early part of the same period a few other species were associated with these in the nearly adjoining region of Durham. But the Durham fauna, like that of Yorkshire, was greatly reduced in number, both specifically and individually, compared with its development in the preceding epoch. Out of its 118 Shell-limestone species only 22 reappear in the Upper Limestone, 6 new species appearing along with them. In the highest portion of this member (at Roker and Hartlepool), the only species that occur are the two Conchifers found in the Brotherton Beds, and



J. W. K. del. Geo. West lith.

W. West, imp.

PERMIAN FOSSILS FROM YORKSHIRE.

Turbo helicinus. In the equivalent strata of the Zechstein there is a similar falling off in the distribution of species; and the same forms are the characteristic fossils there, *Ax. dubius* under its "*Schlotheimi*" character being the most common. It would thus appear that in the whole of the West European area there was a most remarkable decrease in the Permian fauna during the period of deposition of the Upper Permian strata, the decrease being greater towards the close than at the beginning of that period, and affecting the same classes, and even the same species in most cases, in the different parts of that area, thus leaving a similar though exceedingly meagre group of species distributed throughout.

EXPLANATION OF PLATE VII.

Figs. 1, 2, 4, 5, 6. *Rissoa Leighi*, Brown. Five specimens illustrative of its variation of form; magnified about 14 times. Hampole.

Fig. 3. *Rissoa Leighi*, Brown. Young individual; magnified 16 times. Hampole.

Figs. 7, 8. *Natica minima*? Brown. Outer lip of specimen imperfect; magnified 12 times. Hampole.

Figs. 9, 10. *Turritella Altenburgensis*, Geinitz. Magnified 16 times. Hampole.

Fig. 11. *Axinus dubius*, Schlotheim. New variety. Cast; somewhat enlarged. Moorhouse.

Fig. 12. *Axinus dubius*, Schlotheim. New variety. Cast; somewhat enlarged. Conisborough.

March 20, 1861.

The following communications were read:—

1. *Notes on a* Collection *of* Fossil Plants *from* Nágpur, Central India. By Sir Charles J. F. Bunbury, Bart., F.R.S., F.G.S., &c.

[Plates VIII—XII.]

Introduction.—It is now some considerable time since the fine collection of fossil vegetable remains from the district of Nágpur in Central India, which had been presented to the Geological Society by the Rev. Messrs. Stephen Hislop and Robert Hunter*, was entrusted to me for examination and description. Owing to the obscure and equivocal character of many of these remains, the undertaking proved more tedious than I had expected, and there still remain many specimens to which I have not yet been able to give a thorough examination. But, as particular circumstances make it unlikely that I should, for some time to come, have sufficient leisure to devote to this pursuit, I think it best to lay before the Society at once the results of my inquiries as far as they have yet gone, rather than to keep them back for an indefinite time in the hope of completing them. The present paper, therefore, will contain the description of all the Ferns in the collection, and of all those remains of Stems and Leaves of other kinds which I have, to the best of my ability, sufficiently examined; these altogether constitute nearly

* See Quart. Journ. Geol. Soc., vol. xi. p. 348 and p. 369.

three-fourths of the collection. The Fruits and Seeds, of which the specimens are pretty numerous, but obscure and difficult to determine, are reserved for further examination. I may observe, however, that, though numerous in individuals, they seem to be little varied in form and character, and present no outward evidences of a high organization.

The general remarks which form the latter part of this paper are founded, I must observe, not merely on the close examination which I have given to the specimens herein described, but on a general survey of the whole. It is possible that a more minute examination of the remaining fossils (the Fruits and Seeds) may partially modify some of the conclusions I have drawn,—but not, I think, to any very material extent.

FERNS.

1 (A). Glossopteris Browniana, var. *Indica*, Ad. Brongn. Hist. Vég. Foss. p. 223, pl. 62. f. 2. Pl. VIII. figs. 1–4.

This, as appears from the very numerous specimens in the collection, is one of the most common plants of the supposed Jurassic beds of Nágpur. Excepting one doubtful fragment from Kámpti, all the specimens are from Silewádá, and are very numerous, of large size, and in a fine state of preservation; yet even among these it is not usual to find a frond with both extremities perfect. One specimen, though broken at both ends, still measures 14 inches in length, and must have measured at least 17 inches when perfect. Another (almost perfect) is 14 inches long; the largest I have seen is 16 inches long in its present state (with the apex broken off), and must certainly have been 18 inches. On the whole, from a comparison of numerous specimens from this locality, we may say that the full-grown fronds were from 10 to 18 inches in length (exclusive of the stalk), and seldom more than $2\frac{1}{2}$ inches in their greatest breadth. The outline of the frond in all these fine specimens from Silewádá is narrower, more lanceolate, and more tapering to a point, than in Brongniart's original Australian plants, and even than in his figure of the Indian variety (pl. 62. fig. 2). Like the Australian plant, however, it always tapers very gradually to the base, passing almost insensibly into the stalk (of which but a small portion is preserved in any specimen that I have seen); and the greatest breadth is generally above the middle. The apex of the frond, wherever it is preserved, always tapers regularly into a very acute point.

The midrib is remarkably broad, but flattish, and not very prominent, strongly striated, tapering very gradually upwards, and reaching quite to the point. Morris long since remarked (in Count Strzelecki's 'New South Wales,' p. 248) that the venation of the specimens examined by him did not altogether agree with Brongniart's description, and that the reticulation of the lateral veins was not confined to the neighbourhood of the midrib, but that they anastomosed repeatedly at various distances between the midrib and the margin. Brongniart has since repeated (in his 'Tableau des Genres de Vég. Foss.') his original character of the genus, without taking any notice of Morris's remarks. My observations, however, both on the Nágpur specimens and on the numerous Australian ones which I have examined, agree with those of Morris. The lateral veins (which are very fine and close) are repeatedly forked near the midrib, and there form, by the anastomosing of their branches, a conspicuous reticulation, of which the meshes are somewhat oblong. Towards the margin they become nearly parallel, forking very sparingly, and anastomosing at long intervals, so as to form very long and narrow meshes; but still they *do* anastomose here and there, even to the margin. The venation of the New South Wales *Glossopteris* agrees in these characters with that of the Indian plant; and one of Brongniart's figures (fig. 1 A, pl. 62) represents the veins correctly, though somewhat at variance with his own description.

In the Nágpur specimens which I refer to this species, I find some degree of variation in the fineness and closeness of the veins—such an amount of difference, indeed, occasionally, as might at first sight seem to imply a distinction of species; but there are so many intermediate gradations that I do not find it possible to draw the line. I think it probable that these differences may depend partly upon the age of the frond, partly, perhaps, upon various conditions attending the fossilizing process, as I have observed that the apparent closeness of the veins in some recent Ferns is influenced by circumstances in the process of drying.

The position of the fructification is indicated in several of these specimens by small round spots, very regularly arranged in 1 or 2 rows parallel to the margin—the outermost row at but a short distance from the margin, the inner about half-way between the outer and the midrib. When there is only one row, it is always the inner one that is wanting. In these spots I can find no organic structure at all, but only little lumps of the sandstone, as if not only the sori themselves, but the very substance of the frond had decayed or been displaced at these points. I think, however, from the regularity of their form and arrangement, there can be no doubt that they really indicate the places of the sori.

I perceive no trace of scales on the midrib or stalk of even the best-preserved specimens.

M. de Zigno has expressed an opinion that the *Glossopteris Browniana* had a compound or digitate frond, as the allied *Sagenopteris Phillipsii* had; indeed, he quotes a report that a specimen had been found to establish this fact. I confess, however, that I can find nothing in corroboration of his opinion. Among the numerous specimens I have examined of the Indian *Glossopteris* (some of the large slabs of stone from Silewádá containing as many as ten or twelve fronds), I can see nothing to indicate that the leaves were portions of a divided or lobed frond, or were otherwise than simple fronds, like those of our Hart's-tongue Fern, or of the Bird's-nest *Asplenium* (*A. nidus*, L.). Neither can I find any different structure in this respect in the Australian specimens of *Glossopteris* that I have seen, nor does McCoy mention any in his memoir.

Dr. McClelland (Report of the Geological Survey of India, 1850) has indeed figured* a specimen of *Glossopteris* which might at first sight be supposed to show a digitate form of frond; but on examination of the drawing, it is clear that the leaves did not all grow in the same plane, and that, instead of being leaflets of a digitate frond, they are really simple fronds growing in a tuft (as is so common in recent Ferns) from a short thick rhizoma. His description, too, though not very clear, sufficiently indicates that he understood the structure as I do. Such a specimen, nevertheless, ill understood, may easily have given rise to the report quoted by De Zigno.

Notwithstanding this difference in the composition of the frond between the typical species of *Glossopteris* and of *Sagenopteris*, I yet agree with De Zigno in doubting whether the two genera are sufficiently distinct. In specimens of *Sagenopteris Phillipsii* from Scarborough, I find the venation so similar to that of the Australian *Glossopteris*, that it would be very difficult to found a generic difference upon this character. Some of the Indian forms of *Glossopteris* certainly depart more widely from *Sagenopteris* in their venation; but there are others again, as I shall presently mention, which show truly intermediate characters. The fructification of *Sagenopteris* is still entirely unknown; and it is possible that, when discovered, it may prove the two genera to be quite distinct; but in the present state of our knowledge, I see no sufficient reason for keeping them separate.

If it be thought expedient to reunite these genera, the name of *Glossopteris* certainly ought to be retained, as the older and perfectly unobjectionable.

On comparing this Indian *Glossopteris* with the common Australian *G. Browniana*, allowing for the apparent differences produced by the nature of the stone and the state of preservation of the specimens, I can find no satisfactory specific distinction; the venation is essentially the same. We may indeed find Indian specimens in which the meshes of the reticulation near the midrib are larger and broader than in the ordinary Australian plant, and others in which the veins are more strongly recurved; but, in both the Indian and Australian plants, I find so many shades of variation in these particulars, that I cannot attach much importance to them. The general form varies considerably in the Australian specimens, and is often quite as narrow as in those from Nágpur; the apex also varies in the Australian plant, from very obtuse, and even *retuse*, to rather acute, though I admit that it is never, in the specimens I have seen, as acute as in the Indian. I have seen no trace of fructification in Australian specimens, nor is any mentioned by McCoy; on the other hand, I am unacquainted with the rhizoma of the Indian *Glossopteris*. In the absence of these important points of comparison, we cannot feel certain of the specific agreement of the two.

With respect to the affinities of *Glossopteris* to recent Ferns, I am not able to add anything to what Brongniart has said. The form and position of the sori indicate its place either in the tribe of

* Pl. 14. fig. 3.

Polypodieæ or of *Aspidieæ*; but no recent genus of either of those groups has the same venation. In this latter respect some of the *Acrosticheæ* approach nearer to *Glossopteris*; but the reticulation of their veins is always more uniform.

Among fragments of fossil plants from Bloemkop, South Africa, collected by Dr. Rubidge, and exhibited before the Geological Society Nov. 17, 1858, there are two forms which appear allied to *Glossopteris*,—one a narrow, somewhat lanceolate frond, with veins numerous and very fine, resembling in direction those of *G. Browniana*, not very evidently anastomosing (but this was perhaps rendered obscure by the bad state of the specimen); the other consisting of mere fragments, with veins forming a lax and regular network—perhaps more like the venation of *Dictyopteris* than of *Glossopteris*.

1 (B). Glossopteris Browniana, var. *Australasica*, Ad. Br. Hist. Vég. Foss. pl. 62. fig. 1. Pl. VIII. fig. 5.

I find two specimens which have the form usual in the Australian specimens and considered by Brongniart as typical of the species—namely, tongue-shaped or subspathulate, with an obtuse apex. Both are small: the larger, in fine reddish-white sandstone from Bharatwádá, is 5½ in. long, 1¾ in. in maximum breadth; the other (in a coarse, blackish, micaceous sandstone from the foot of the Mahádewa Hills) 3½ in. by 1 in. Venation rather ill preserved and indistinct in both, but apparently agreeing with the Australian specimens.

2. Glossopteris musæfolia, n. sp.? Pl. VIII. fig. 6.

Several specimens of a *Glossopteris*, both from Silewádá and from Kámpti, appear to belong to a different species from that first described, though none of them are complete enough to be quite satisfactory. The direction of the veins, which (unless very near their base) are straight, and almost perpendicular both to the midrib and to the margin, might cause the plant to be taken for a *Tæniopteris*; but these veins are in fact dichotomous, and anastomose repeatedly near the midrib. They are extremely numerous, very fine and close, and for the greater part of their length quite parallel. Besides, the frond is much broader than in *G. Browniana* (3 to 4 in. broad), and appears to have been quite rounded at the apex; the actual apex however is not perfect in any specimen that I have seen, nor do any show the form of the base. The frond appears to have been of thin substance, and apt to split or tear transversely in the direction of the veins, like the leaves of the Banana (*Musa*). One specimen shows remains of fructification in round spots, arranged as in *G. Browniana*.

Ferns are so variable that I feel some doubt whether this may not hereafter prove, when better known, to be a variety of *G. Browniana*. I think I see in some specimens a tendency to intermediate gradations of character; yet in living Ferns, as far as I have been able to observe, the direction of the veins appears to be very constant in each species, even in such variable plants as *Scolopendrium officinarum* and *Asplenium nidus*. As the characters of the present plant are sufficiently striking, I think it best to distinguish it, provisionally, as a species. It may be characterized as follows:—

Glossopteris muscæfolia.

Frond broadly oblong, rounded and very obtuse at the apex; side-veins very slender, very much crowded, dichotomous, nearly perpendicular to the midrib and the margin, near the base only oblique and anastomosing.

Glossopteris frondosa, McClelland*, has some resemblance to this, especially in general form; but neither the figure nor the description enables me to identify the two. If they be the same, the most important characters of the venation are overlooked by that author.

3. Glossopteris leptoneura, n. sp.? Pl. IX. figs. 1–4.

Numerous specimens in sandstone from Kámpti; the fronds generally in great numbers on the surface of each slab of sandstone, lying confusedly together, so that hardly any frond is visible in its whole length: it appears that the plant must have grown in great abundance in particular spots. I at first took this species for the *Glossopteris angustifolia*, Ad. Br., which it resembles in outline; but, judging from the figure and description of that species†, the venation is essentially different. In *G. angustifolia*, the veins appear to be coarse and rather distant, and sparingly anastomosing near the midrib only; in our Kámpti plant they are very fine and close, and anastomose *repeatedly* throughout their length, even near to the margin, forming almost as regular a network as in *Sagenopteris Phillipsii*. Our plant agrees more nearly (indeed very nearly) with *G. linearis*, McCoy; but the veins are much more oblique than they are described in that species, and quite as much so as in *G. angustifolia*.

The frond of this *Glossopteris* is, like that of *G. linearis*, very narrow in proportion to its length, with nearly parallel margins; some of the most nearly complete specimens are $4\frac{1}{2}$ to 6 inches long, with a breadth of only half an inch; the apex acute, but less remarkably so than in the Nágpur form of *G. Browniana*; the base tapering very gradually into the footstalk.

One very small frond, from Kámpti, apparently a young plant of this species, has preserved the whole of its leafstalk or stipes, which I have not seen in other instances; this stipes is much shorter than the frond, narrow, and rather suddenly dilated at the base.

Intermixed with the narrow linear fronds which I have described, I find others, in much smaller numbers, of a broader form, lingulate or somewhat lanceolate, but with precisely the same venation as the narrow ones. They have the form of *G. Browniana Indica*, but are still, I think, clearly distinguishable by their finer veins and the more uniform reticulation of these veins,—the venation, in fact, being that of *Sagenopteris*. These broader fronds appear to me to belong to the same species with the narrow linear ones: it may be doubted

* Report of Geol. Survey of India, p. 55, pl. 15. f. 3.

† Ad. Brongn. Hist. Vég. Foss. 224, pl. 63. f. 1.

(as in the case of the narrower and broader fronds of *Sagenopteris Phillipsii*) whether the two are to be considered as varieties, or (which I am rather inclined to believe) as two different forms of frond which may occur on the same plant, as many recent ferns have biformed fronds. I can find no trace of fructification on any of the specimens of *G. leptoneura*; nor, again, is there anything to indicate that they were otherwise than really simple fronds.

If *Sagenopteris* is to be distinguished as a genus from *Glossopteris* by its venation, the present species will be referable rather to the first of these genera; but it appears to me that this and the *G. linearis*, McCoy, are rather to be considered as connecting links tending to reunite the two supposed genera.

The distinctive characters of my *Glossopteris leptoneura* may be thus expressed:—

Frond narrow, nearly linear (qu. sometimes lanceolate?), rather acute at the apex, tapering very gradually at the base into the stalk. Midrib narrow, continued to the apex. Side-veins very fine, very oblique, arched, dichotomous, anastomosing, and forming a complete network from the midrib to the margin.

4. Glossopteris stricta, n. sp.? Pl. IX. fig. 5.

Of this there are very few specimens; but the plant appears a distinct one, almost ambiguous in characters between *Glossopteris* and *Tæniopteris*—at first sight more resembling the latter. Midrib very broad and strong. Lateral veins very numerous and close, perpendicular to the margin (as in *Tæniopteris*) and almost straight, only a little arched at the very base; more than once forked, and *anastomosing near their base*—that is, near the midrib. This venation agrees pretty closely with that of *G. musæfolia*, No. 2; but the frond is of a different form, narrow, strap-shaped, with nearly parallel edges, only very slightly widening upwards; it has a much more firm and rigid appearance, showing no tendency to be waved or crumpled. The best specimen (with both ends broken off) is 9 inches long, and rather more than 1 inch in greatest breadth. The anastomosing of the veins is most apparent in the lower part of the frond.

Loc. Silewádá and Kámpti.

5. Pecopteris? Pl. IX. figs. 6–8.

A single specimen from Kámpti. A doubtful *Pecopteris*, with considerable resemblance in outline, and apparently also in the venation (which however is very obscure), to *P. Plukenetii*, Ad. Br. The specimen is ill preserved; but the frond appears to have been large and very compound—tripinnatifid at least. The portions which are preserved are probably the upper or terminal part of the frond (which is bipinnatifid) and two of the lateral pinnæ or branches (also bipinnatifid). Main rachis slightly winged or bordered. Pinnæ (of the second order) long, nearly linear in their general outline, spreading nearly at right angles to the main rachis, pinnatifid; ultimate pinnules nearly round (rounder than in any form of *P. Plukenetii* figured by Ad. Br.), alternate or, in parts, nearly opposite, united from their base nearly half-way up, entire, diminishing very gradually towards the extremity of the pinna; the terminal one small, roundish, not much separated from the next. Veins (very indistinct in the specimen) scarcely agreeing with the generic character of *Pecopteris*, but well enough with those of *P. Plukenetii*, as represented by Ad. Brongniart, tab. 107. fig. 3 A; midrib faint, not reaching to the apex, but breaking into very oblique and repeatedly forked side-veins.

In outline this plant strongly resembles *Odontopteris Schlotheimi*, Ad. Br. t. 78. f. 5, except that the pinnules are smaller and more numerous on each branch; but the veins are quite different. The venation approaches to that of some species of *Sphenopteris*; but the plant cannot well be referred to that genus, for the form and position of the pinnæ and pinnules are those of a *Pecopteris* of the section *Unitæ*. It has much resemblance to a fern from the anthracite-slates of Savoy (No. 9 of my paper in Quart. Journ. Geol. Soc., vol. v. p. 140), which is referred by Heer to *Pecopteris Plukenetii*. One of McClelland's* figures of his *Pecopteris affinis* (pl. 13. fig. 11 *b*) has a resemblance in outline to this plant; but the figure is too imperfect to allow of identification.

6. Cladophlebis. Pl. X. fig. 1.

A very small fragment of a Fern (from Kámpti), not to be named or identified from such very imperfect materials, perhaps belonging to *Pecopteris Lindleyana* (of which I have seen no specimens nor satisfactory description), evidently different from any other in this collection. It may be referred to Brongniart's genus *Cladophlebis*† (corresponding to *Pecopteris*, section *Neuropteroides*, of the Hist. Vég. Foss.), the venation being intermediate between that of *Neuropteris* and of *Pecopteris*. Pinnules about as large as those of *Neuropteris Loshii*, and a good deal like them in shape, but more oblique; the base not cordate, but oblique or unequal-sided, and (as in *Cladophlebis pteroides*) only partially attached to the rachis. Midrib more continuous than in *Neuropteris*, but less than in the typical Pecopterids; side-veins very oblique, but less arched, less crowded, and more sparingly branched than in *Neuropteris* proper.

I find another fragment from Kámpti, which I am inclined to refer to this same plant, although it is in a state which renders its determination doubtful. It appears to be a portion of a Fern, with the leaflets reduced (probably by decay previous to fossilization) to a skeleton, little else remaining of them than the veins; whence the fragment might be taken at first sight for some delicate *Sphenopteris*. It is well known that the *Sphenopteris myriophyllum*, Brongn., was founded on a specimen in a similar condition.

7. Tæniopteris danæoides, McClell.? (*Glossopteris danæoides*, Royle?) Pl. X. fig. 2.

The specimens of this (in sandstone from Kámpti) are but few and very imperfect; but they belong (as far as can be seen) to Brongniart's genus *Tæniopteris*, and may be the same species with the

* Report of Geological Survey of India, 1850.

† Tableau des Genres des Végétaux Fossiles.

Glossopteris danæoides of Royle, which is very properly referred by McClelland to *Tæniopteris*. This Nágpur plant has also a striking resemblance (as far as can be judged from such fragments) to the *Tæniopteris major*, L. and H.; but the imperfect state of our materials does not allow us to identify them.

Is it not possible that this plant, and also the *Tæniopteris major*, may belong to *Cycadeæ*, or at least to the same family with *Pterophyllum*? Dr. Murray, of Scarborough, first suggested this to me while comparing the specimens of *Pterophyllum comptum*, L. & H., with those of *Tæniopteris* in his collection. In one of his specimens, the lower half of the leaf has the characteristic form and division of *Pterophyllum comptum*, while the terminal half is altogether undivided and has the appearance of a *Tæniopteris*. Another specimen might be taken for a *Tæniopteris*, but shows towards its middle a tendency to split into pinnules.

8. Filicites. Pl. X. fig. 3.

A small frond, from Silewá*d*á, unfortunately too imperfect to be satisfactorily described or referred to its proper genus, but curious. At first sight it might be taken for a small specimen of *Baiera Huttoni*, Ad. Br. (*Cyclopteris digitata*, L. & H.); but the venation is quite different: instead of numerous, equal, regularly radiating, dichotomous veins, it has a single well-marked midrib in each lobe; the lateral veins extremely indistinct, but apparently going off very obliquely from these ribs. The lobes preserved in this specimen are four in number; but there were probably seven, gradually diminishing in size each way from the middle one; not very deeply separated, of an obovate oblong form, and very obtuse. Base of frond wanting. Mr. Hislop has labelled this specimen as "small *Glossopteris*;" and I think it not impossible that it may belong to a seedling plant of *Glossopteris*; but there is no evidence to connect it satisfactorily with that genus.

9. Filicites (qu. Glossopteris, sp.?). Pl. X. fig. 4.

This is unfortunately a very imperfect fragment, but of a curious plant, unlike any other I have seen in a fossil state,—undoubtedly a Fern, but scarcely referable to any genus hitherto established; therefore, rather than attempt to found a new genus on such imperfect materials, I leave it under the vague name of *Filicites*. It is from Kámpti.

Stipes (incomplete) $2\frac{3}{4}$ inches long in this fragment, very broad and flat, bearing in its upper part three leaves or leaflets on one side and one on the other (the others which ought to have been on this side being destroyed). Leaflets very incomplete, more than half of each being broken off; but they appear to have been of considerable size, entire and undivided, and probably of an oblong or lanceolate form—not, however, tapering gradually into a stalk as in *Glossopteris*, but sessile on the main stalk, attached to it by a broad oblique base; closely placed, so as partly to overlap one another, and apparently increasing progressively in size upwards, the lowest being smallest. The venation is very ill preserved and very indistinct, but appears nearly, if not quite, that of *Glossopteris*. Midrib narrow but sharply marked; side-veins numerous, fine, oblique, but scarcely arched, sparingly dichotomous; and I *think* they occasionally anastomose; but this is not very distinct. Texture of the frond seemingly thin.

This may possibly be a genuine *Glossopteris*, but differs remarkably from those hitherto described in the composition of its frond. It certainly cannot be a state either of *G. Browniana*, or of any of the other species described in this memoir. Even supposing the apparently simple fronds of these species to be leaflets of a compound frond (which is very improbable), they are constantly characterized by a form much narrowed towards the base, and tapering very gradually into a petiole of some length; whereas in this, the leaflets neither taper gradually to the base, nor have any partial stalk, but are attached at once by a broadish base to the main stalk.

10. Nœggerathia? (Cyclopteris?) Hislopii, n. sp. Pl. X. fig. 5.

The leaves, or (as is perhaps more probable) detached leaflets, which occur in several pieces of stone from Bharatwádá, and which Mr. Hislop has marked as "*Cyclopteris*," appear to me to belong rather to the genus *Nœggerathia*, or at least to the family of *Nœggerathieæ* of M. Brongniart. None of the specimens are nearly complete; but by a comparison of different fragments we see that the leaf was of a narrow wedge-shape, widening gradually upwards from a narrow base—not however quite symmetrical, but very slightly oblique; the terminal portion, which is well seen in one fragment, very conspicuously oblique, rounded at the actual apex, and from thence sloping away with a gentle curve, and forming a very obtuse and rounded angle with the other (lower) margin. The leaf (as far as can be judged from mere impressions) appears to have been of a firm and rather rigid texture, with a smooth surface. The largest fragment I have seen is about 5½ inches long; the breadth in no part seemingly much exceeding 1 inch. Veins numerous, all equal and uniform, with no appearance of a midrib, strong and rather coarse, radiating from the base, but spreading very gradually and forming very small angles with one another, so that for any short distance they appear nearly parallel; they are once or twice forked, but very sparingly, the branches diverging very gradually, and all end in the terminal margin.

This plant may very possibly be a Fern; but the same reasons which led M. Brongniart to consider the *Nœggerathia* as allied to the Cycads induce me to think that this also is rather to be ranked with that family than with the Ferns. The forked veins, indeed, are unusual in *Cycadeæ*, but in *Ceratozamia Mexicana* the veins are occasionally forked, and in *Stangeria paradoxa* they are constantly so. In the genus *Otopteris* or *Otozamites*, which M. Brongniart refers without doubt to *Cycadeæ*, the veins are regularly and repeatedly forked; at least, such is the case in *Otozam. acuminatus* and *O. obtusus*. The breadth and coarseness of the veins in our Nágpur plant, and a certain appearance of rigidity about the leaf, look to me rather like a Cycad than a Fern. All these reasons, however, are far from conclusive; and I must admit that, to me, it still remains a matter of much doubt to which of the two families this plant should be referred. If a Fern, it must from its technical characters be placed in *Cyclopteris*, although it evidently has no *natural* affinity to any of the plants comprehended under that name. It might be named *Cyclopteris Hislopii*.

The dichotomy of the veins, their equality and uniformity, and the absence of any trace of transverse connecting veins, plainly show that it is not a Palm.

A small leaf or leaflet in sandstone from Kámpti agrees with this in venation, and evidently belongs to an allied species, perhaps not to the same; for the outline is different, being in the Kámpti plant lanceolate and nearly symmetrical, instead of cuneiform and oblique. This specimen is better preserved than those from Bharatwádá, and shows the form of its base, though not its actual connexion with the stalk or stem; there is an appearance of thickening at the base, as is seen in several of the *Cycadeæ*, and some indication of its having been connected with the stalk by an articulation. The leaf appears to have been of a thick and leathery texture; the veins are rather indistinct; the surface appears minutely granulated, but I am not quite certain whether this is really owing to the texture of the leaf itself. This specimen may probably belong to a distinct species; but our materials being so very imperfect, I do not think fit to give it a separate name.

A specimen, apparently belonging to this plant, from Tondakheiri, has been labelled "*Cyclopteris* with fructification." It is not in a good state of preservation; the apex appears wrinkled or thickened; the veins (or the spaces between the veins) swollen and distorted, and as it were knotty or granulated at their extremities. This appearance has been taken for fructification; and if it were so, there could be no doubt of the plant being a Fern. But I confess that, on a close and careful examination, I can see nothing sufficiently distinct and definite to satisfy me that this peculiar appearance can be referred to fructification. The specimen unfortunately is ill-preserved; it exhibits merely an impression—and not a sharp or clear one—of the original in a sandstone not of very fine grain; and I think it possible that the swollen and wrinkled appearance at the apex of the leaf may be produced accidentally by something in the nature of the stone or the process of fossilization. The evidence of its being the fructification of a Fern is not at present sufficiently clear to me to overcome the reasons which induce me rather to refer the plant to *Cycadeæ*, or a neighbouring family.

Plants of doubtful Affinity.

11. PHYLLOTHECA INDICA, C. B. Pl. X. figs. 6–9; and Pl. XI. figs. 1 & 2.

Specimens are numerous in the fine-grained sandstone from Bharatwádá; all very fragmentary, but some of the fragments delicately preserved. There are other specimens also from Bokhárá, Kámpti, Silewádá, and Barkoi. It is difficult to form a clear idea of the general form and habit of the plant; but the specimens give satisfactory information as to the leaves and sheaths, their relative position and connexion. Some of them show conclusively the accuracy of Brongniart's original statement, that the leaves are prolongations of the teeth of the sheaths. Lindley (followed by Unger in his 'Synopsis') conjectured that Brongniart had been deceived, and that the leaves really surrounded the sheath, springing from below it; but the correctness of the original description has been confirmed by the observations of Morris* and McCoy,† on specimens from New South Wales; as well as by the later ones of Baron Achille de Zigno on two new species of the genus discovered by him in the Jurassic rocks of the Veronese territory ‡. The specimens before me are, I believe, the first that have been described from India §. They were very correctly referred by Messrs. Hislop and Hunter to the genus *Phyllotheca*; and it is not yet clear to me whether they are even specifically distinguishable from those of New South Wales.

Some of these fragments show most unequivocally the continuity of the narrow leaves with the sheaths; that, in fact, the leaves are simply the elongated teeth of the sheaths; or, to express it in a different way, that the sheaths are formed of the united bases of the leaves. The sheaths in this Bharatwádá plant are not closely pressed to the stem, as described in the original *Phyllotheca australis* of Brongniart, and in McCoy's *P. ramosa*; they widen more or less rapidly upwards, and more rapidly in the upper part, so as to be somewhat funnel-shaped or bell-shaped; on the upper parts of the small branches they appear to cover the whole, or nearly the whole, length of the internodes. These sheaths are strongly and regularly furrowed; the furrows appear to correspond in number to the leaves, and to be prolonged into their midribs. Leaves numerous in each whorl, but I have not yet found any specimen sufficiently perfect to show their exact number; they are linear, very narrow, longer than the sheaths, with a distinct midrib; in direction sometimes erect, more often spreading at various angles, and very often recurved. The sheaths seem to be deciduous; at least I can find no trace of them on what appear to be stems and older branches of the same plant, which are regularly and distinctly furrowed and jointed, like a *Calamites*. The furrows do not, however, alternate at the joints, as in all the *Calamites* except *C. transitionis* Göpp.; the ridges and furrows of each internode are in the same line with those of the next. McCoy describes the branches of his *P. ramosa* as originating "directly over the joints," and being therefore "within and axillary to the sheaths." The same is evidently the case with *P. Brongniartiana* of De Zigno. Some of the Nágpur specimens show branches,

* Strzelecki's New South Wales, p. 251.

† Annals of Nat. History, v. p. 20 (1847).

‡ Flora Fossilis Formationis Oolithicæ, pp. 59, 60, tabb. 7, 8.

§ No species of *Phyllotheca* is noticed by McClelland in his enumeration of Indian fossil plants (Report of Geol. Survey of India, Calcutta, 1850).

but unfortunately their origin relatively to the sheaths is obscure; for they spring from what appear to be the old stems, on which I can find no sheaths remaining. They are inserted on the stem with a distinct articulation, as in *Equisetum* and *Calamites*; but their insertion appears to be exactly on the articulation of the stem, and not below it. In the *P. ramosa* and *P. Brongniartiana*, the origin of the branches is unequivocal; and, though less evident, it is probably the same in this plant. I think, with McCoy, that this character decidedly removes *Phyllotheca* from any near affinity with *Equisetum*, as one of the especial and most peculiar characters of the latter genus is the origin of the branches from *below* the sheaths.

Some further light is thrown on this question by a specimen*, from Silewá*dá* near Nágpur, of what appears to be an old stem of a small *Phyllotheca*; the arrangement of the ridges and furrows being such as is usual in this genus, and not such as prevails in *Equisetum* and *Calamites*. Here there is a scar, doubtless of a branch, seated exactly *on* one of the articulations, and perfectly similar, except in its small size, to what we see in *Calamites ramosus*, Ad. Br. No trace of a sheath remains.

Some of the flattened stems, which I suppose to belong to this *Phyllotheca*, are above an inch broad, strongly and coarsely furrowed. As they are pressed quite flat, without being crushed or distorted, we must suppose either that they were of a soft and herbaceous substance, or that the wood had entirely decayed before they were fossilized, leaving only a tube of bark.

It is not improbable that the remains of *Phyllotheca* in this Nágpur collection may belong to more than one species, as the great difference in the fineness or coarseness of the furrows on stems of about the same diameter may seem to indicate; but I cannot satisfy myself as to the distinctions.

Our materials being still so incomplete, I feel by no means sure that further discoveries may not prove this Indian *Phyllotheca* to be identical with one or other of the Australian species. Yet, as it does not *exactly* agree with the description of any of them, and as there is a *primâ facie* probability that plants from such distant countries are not the same, I will provisionally name this one *Phyllotheca Indica*.

Its characters may be given thus:—

Stem branched, furrowed; sheaths lax, somewhat bell-shaped, distinctly striated; leaves narrow linear, with a strong and distinct midrib, widely spreading and often recurved, nearly twice as long as the sheaths.

The original *Phyllotheca australis*, Brongniart, and the *P. ramosa*, McCoy (according to the descriptions), differ from this in having the stem smooth or slightly striated, not furrowed, and the sheaths fitting closely to the stem; *P. australis* further in its simple stem, and leaves without a midrib. *P. Hookeri*, McCoy, which of the described species comes nearest to our Indian one, appears to have much larger sheaths and longer leaves, as well as a simple stem.

* See Pl. X. fig. 6.

The real affinities of *Phyllotheca* to existing plants are scarcely to be determined in the present state of our knowledge. It appears, as Brongniart observes, to be nearly allied to the fossils called *Asterophyllites* and *Annularia*, and most probably also to *Calamodendron*, Ad. Br.,—all these having essentially similar characters of ramification, with verticillated one-ribbed leaves. The position of the branches shows that it cannot be nearly akin to *Equisetaceæ*. McCoy's arguments to prove it a near ally of *Casuarina*, do not appear to me conclusive. The catkin which he has figured as the *male* flowers (see his pl. 11. fig. 1), strikes me as agreeing well enough in its general structure with the known fructification of *Asterophyllites* and *Annularia* (see Geinitz, 'Steinkohlenform. Sachsen,' tab. 17. fig. 3, tab. 18. fig. 8, 9). No other kind of fructification, as it seems, has yet been found in connexion with any *Phyllotheca*. If these plants belonged to the group of the *Casuarinæ*, it is hardly probable, abundant as they are, that some trace would not have been found of the remarkable seed-vessels of that family.

12. Vertebraria? Pl. XI. fig. 3.

Some impressions in sandstone from Kámpti, Tondakheiri, and the Mahádewa Hills, and in bituminous shale from Barkoi, labelled as "*Vertebraria*," have certainly a *primâ facie* resemblance to the published figures of the *Vert. Indica*, especially to that in McClelland's Report, tab. 14. fig. 1; but I can hardly reconcile the appearances presented by these specimens with the structure described by McCoy and De Zigno. The specimens indeed appear to be merely impressions, consequently not showing a transverse fracture, nor exhibiting anything of the radiated structure described in *Vertebraria*. But the Kámpti specimens are *branched*, a circumstance not hitherto recorded in any *Vertebraria*; and branched in a manner which I cannot reconcile with the received explanation of the structure of that genus. Those from Tondakheiri and Mahádewa are unbranched, but otherwise agree with those from Kámpti. The stem (or whatever the columnar body is to be called), is from $\frac{1}{4}$ to $\frac{3}{4}$ inch broad; along the centre of it runs what we must for convenience call the axis, which in the best specimens (from Kámpti) appears as a deep narrow channel or furrow, but in some others as a ridge. This is not straight and even, but more or less flexuous in direction, and more or less widened out in some parts. From it proceed to each side in an irregularly alternate order, and at very unequal distances, what seem to be partitions, dividing the surface of the fossil on each side of the axis into portions of various lengths. The surface between these partitions is irregularly prominent or gibbous, and in most of the specimens shows no decided traces of organic structure. But in the largest specimen from Kámpti, I observe appearances which seem clearly to indicate a continuous cellular tissue, as of the cuticle of a stem or root: the surface exhibits delicate but distinct longitudinal lines, cross-barred by fainter aud very short transverse ones; the spaces between being a little raised. The appearance is exactly that of an epidermis formed of narrow rectangular cells.

The branches are very irregularly alternate; very often, but not constantly, they are opposite to one of the supposed partitions; they are of small diameter in comparison with the body from which they proceed, but various and irregular in thickness, and not less various in direction; in many of them we can trace an axis, like that of the main body on a small scale. Many of them are again subdivided, and with a like irregularity.

Now, this striking irregularity of ramification appears to me to be very much at variance with the characters of the genus *Sphenophyllum* and the family of *Calamiteæ* (or *Asterophylliteæ*) to which *Vertebraria* is referred by De Zigno and others. In *Sphenophyllum, Asterophyllites, Annularia,* and in those *Calamites* or *Calamodendra* which branch, the branches invariably spring from the articulations of the main stem, with which they are themselves articulated at their base; and their arrangement is really symmetrical, though the symmetry is sometimes disguised by abortion. In this fossil, on the contrary, the branches are continuous with the main trunk, not articulated, and are in every way irregular and unsymmetrical. I conclude, therefore, that the so-called *Vertebraria* from Kámpti is not a *Sphenophyllum,* nor one of the *Asterophylliteæ.* On the other hand, all the characters of the ramification appear to me to favour the conjecture that these supposed *Vertebrariæ* are *roots* of some large plant.

The true original *Vertebrariæ,* according to McCoy, owe their singular form to densely compacted whorls of leaves surrounding without interruption a slender stem. That the supposed *Vertebrariæ* of Kámpti are not of this nature is rendered evident, not only by their ramification but also by the character of the cellular structure observable on the surface of one specimen, which I have already described.

In the unbranched specimens from the Nágpur district, the indications of their nature are not so clear; and their appearance might easily lead to their being classed with the true *Vertebrariæ.* They seem to me, however, to be in reality of the same nature with the branched specimens from Kámpti. Nor can I at all understand how distinct (though crowded) whorls of leaves could, in the fossilizing process, have remained so closely and uniformly pressed together as to present the appearance of a continuous columnar body through the whole length of the specimens. In no part of the best of these pieces can I detect any appearance at all like leaves.

On the whole, then, I am of opinion that the branched specimens from Kámpti, which have been taken for *Vertebrariæ,* were the roots of some plant, possibly of *Phyllotheca*; that they had probably a woody central axis of small diameter; that between this axis and the outer coat or rind (which probably consisted of loose cellular tissue) there was a hollow, traversed at irregular distances by incomplete partitions, which connected the outer coat with the axis. The unbranched specimens were most likely also fragments of roots, though this is not quite so clear. The original *Vertebrariæ, V. Indica* and *V. australis* (*Sphenophyllum radiatum* and *S. australe,* Zigno), must evidently, from the descriptions, be of an entirely different structure.

13. Knorria? (Conifer?) Pl. XII. fig. 1.

A single fragment, in a fine-grained red sandstone from Mángali. This is a cast of a piece of stem or branch, about $\frac{1}{2}$ inch broad, distinctly marked with numerous small, roundish, dot-like leaf-scars, arranged with great regularity in a quincuncial or spiral order; each scar distant rather more than $\frac{1}{8}$ inch from those nearest to it. No appearance of definite areolæ as in *Lepidodendron*, but a narrow furrow or crack running down from each leaf-scar for some distance in a straight line. The form and size of the scars clearly indicate that the leaves were slender and needle-shaped.

This fragment is perhaps technically referable to *Knorria*, and *may* have belonged to a Lycopodiaceous plant; but its appearance is so strikingly like that of a small branch of a Spruce-fir stripped of its leaves, that, in the absence of any positive evidence to the contrary, I am strongly inclined to believe it to be Coniferous.

14. Rhizome of a Fern? Pl. XII. fig. 2.

A specimen from Mángali, referred (doubtfully) by Mr. Hislop to *Lepidodendron*; in a very unsatisfactory state of preservation, but interesting as having more the look of a genuine Coal-measure fossil than any other in the collection. Appears to be a small portion of the surface of a flattened stem, with numerous scars (qu. leaf-scars?) arranged in somewhat of a spiral or quincuncial order, but with a good deal of irregularity; the scars ill-preserved, but seemingly forming small pits or depressions (as in *Stigmaria*) of a circular or transversely elliptical form, with a small central boss or protuberance; the surface between these pits marked with various wavy transverse wrinkles, which partly enclose the scars, but do not form definite areolæ as in *Lepidodendron*. The appearance is a good deal like some varieties of the so-called *Stigmariæ*, under which name are doubtless included the roots of *Lepidodendra* as well as of *Sigillariæ*. The scars are not, however, arranged with the symmetry characteristic of *Stigmaria*. Nevertheless, if well-marked *Lepidodendra* or *Sigillariæ* had been found in the same beds, I should have considered it, with little doubt, as a fragment of a root belonging to one of those families. But as I find nothing else among the Nágpur fossils to support such a notion, I am more inclined to conjecture that it may have been a fragment of the rhizome of a Fern.

15. Stem.

Apparently an impression of a large flattened stem, with something of the appearance of a *Sigillaria*; but the ribs and furrows are very irregular, perhaps casual, and of the scars only a few remain; these are very small, indeterminate in form and character, showing a tendency to an arrangement in vertical rows, but not very distinctly. The specimen is from Silewádá.

16. Stem. Pl. XII. fig. 3.

This specimen is from Silewádá, and appears to be an impression of a large, broad, flattened stem, without distinct character except one single, very large, and remarkable scar. This scar is of a roundish oval form, nearly $1\frac{1}{2}$ inch in its greater diameter, and about $1\frac{1}{4}$ inch in its lesser; slightly prominent, and well defined all round by a slight furrow dividing it from the general flat surface. It encloses a smaller scar or areola, apparently of corresponding form, but indistinct in part of its outline; towards the centre there appear to be some slight tubercles or vascular scars, but very obscure. From one end (probably the lower) of the large scar, proceeds a kind of appendage, tapering downward to a point, like the downward prolongations of the leaf-scars in *Lepidodendron.*

This scar, by its general form and appearance, reminds one somewhat of the leaf-scars of *Lepidodendron* or of *Caulopteris,* though on a very large scale; but, as there is only one on the whole surface of this portion of stem (nearly $1\frac{1}{2}$ foot long, and in parts 8 inches broad), it cannot be supposed to be the scar of a leaf. Does it indicate the place of insertion of a disarticulating branch, or of a cone or some other kind of fructification? I feel at a loss to decide, the characters being so slight.

The remainder of the surface of this impression is merely marked with irregular oblique wrinkles.

17. Yuccites? Pl. XII. fig. 4.

A specimen from Kámpti, very imperfect, but with much the appearance of a leaf of an endogen, such as a *Yucca* or *Dracæna.* Too incomplete for its length to be determined; but the portion best preserved is about a foot long, and $\frac{3}{8}$ in. broad in the widest part. Appears to have been sword-shaped or ribbon-shaped, tapering gradually towards the apex; the actual point not preserved; veins fine, close, simple, and parallel, giving a finely striated appearance to the surface, with some stronger ones here and there. This last character seems to show that it is not a leaflet of a Cycad; nor do I think it was a leaflet of a Palm, for there is no appearance of a keel or fold along the middle. The base is wanting; consequently we do not know how it was inserted on the stem or stalk.

General Remarks on the Fossil Plants from Nágpur.

1. The first thing that strikes us is the paucity of distinct forms in proportion to the abundance of specimens. This paucity is even greater than one usually observes in collections from the palæozoic coal-fields of Europe or America, and is strongly contrasted with the rich variety of forms presented by most of the tertiary plant-deposits, especially by the miocene formations in Germany and Switzerland*. Everything points to the conclusion that the plant-bearing deposits of Nágpur (and seemingly also the others in India of the same age) were formed in districts which had a limited and monotonous flora, singularly poor in species, though abundant in individuals, and very probably luxuriant in growth. It would

* See Göppert on the Fossil Flora of Schossnitz; Wessel and Weber on the Brown-Coal of the Rhine; Heer, and others.

be rash to conclude that such were general characteristics of the Indian flora in those times. Some might be disposed to account for this monotony by supposing that the fossil plants of Nágpur are merely the scanty remaining fragments of a rich vegetation; and that the other plants with which they were associated, being less adapted for preservation, have entirely perished; but it is hardly possible to admit this explanation when we observe the remarkable variety of vegetable forms in the tertiary plant-beds, which must also have been deposited under water. We do not know of any conditions which would account for the preservation of so many various forms in the one case, and of so few in the other.

2. Another and very striking characteristic of this Nágpur fossil flora, is its close analogy with that of the coal-formation of Australia*. The prevailing plant in each of the deposits is a *Glossopteris*, and it appears (as far as we can judge in the present state of our knowledge) to be actually the very same species in both. My *Glossopteris leptoneura*, an abundant plant in the Nágpur beds, is very closely allied to the Australian *Glossopteris linearis*†. Another most abundant plant of the Nágpur deposit is a *Phyllotheca*, a genus especially characteristic of the Australian coal-formation; and the species, though not identical, is very similar to those of New South Wales. I may add the genus *Vertebraria*, which, though I have met with no certain evidence of its occurrence in the Nágpur district, is known to be common to the Bengal and Australian coal-fields‡. Thus it appears that those vegetable forms which are most striking by their peculiarities, and most characteristic by their abundance, are common to these two distant countries. At present, as is well known, the vegetation of extra-tropical New South Wales is very widely different from that of continental India. If, indeed, we compare *tropical* Australia with India, we find, as Dr. Hooker has shown§, a very marked agreement between their floras; nearly 500 species being common to the two. These indeed are plants of very different character from those which occur as fossils in either country, and afford very different climatic indications; they are the plants of a dry climate and of open and arid countries; whereas the fossil plants must, in all probability, have grown in or near extensive swamps or large bodies of water. It is however worth observing that, *where* the physical conditions of the two countries are nearly similar, there is at present this marked agreement between their floras. It is also to be observed that in each of the fossil floras which we are comparing, the Ferns are the predominant family, and that the Ferns of Australia at the present day are among the least peculiar portions of its vegetation. Several species of this family are common to India and New South Wales; such are *Drynaria irioides*, *D. quercifolia*, *Asplenium nidus*, *Davallia elegans*, *Cheil-*

* See Morris in Strzelecki's New South Wales; and McCoy in Ann. Nat. Hist. v. p. 20.

† And may possibly not be specifically distinct from it.

‡ See McCoy *ut supra*, and De Zigno, Flora Foss. Form. Oolith.

§ Introductory Essay on Flora of Australia, p. 42.

anthes tenuifolia, and *Gleichenia Hermanni.* When, therefore, the climatic or local conditions were such that the mass of the vegetation consisted of Ferns, we need not be surprised to find a much greater agreement than now exists between the two countries.

3. Next, as to the geological indications afforded by these Nágpur plants. Messrs. Hislop and Hunter consider the age of this deposit as Oolitic (Jurassic); McCoy inclines to the same conclusion with regard to the coal of New South Wales; and De Zigno, in his writings on the fossil flora of the Oolite, has without hesitation included under that category the coal-formations of both India and Australia. On the other hand, Prof. Jukes (as quoted by Dr. Hooker*) seems to hold that the coal-formation of Australia is palæozoic. It is very difficult, looking to the points of agreement I have already enumerated, to believe that the Indian and Australian fossil floras† were far removed in time. If the resemblances between them are not worthy of confidence, still less then can we trust to the analogies of either with those of Europe.

The fossil flora of Nágpur is certainly in its general aspect more like that of the Jurassic than of the Carboniferous age. I do not find in it, however, any plant which I can determine to be *specifically* identical with one belonging to the European Oolite. The *Tænio-pteris* (*T. danæoides*?) from Nágpur is not, perhaps, satisfactorily distinct from *T. major* of the Yorkshire Oolite; but our materials do not allow us to identify it with that species. The genus *Glosso-pteris*, so especially characteristic of the Indian and Australian plant-beds, contributes much to give to those formations a *mesozoic* rather than *palæozoic* aspect, since it is perhaps, as a genus, undistinguishable from *Sagenopteris*, of the Oolite and Keuper, while, on the other hand, it has little resemblance to any Ferns of the Carboniferous age. Nevertheless, a certain degree of caution must be observed in concluding that particular *genera* of Ferns are absolutely characteristic of particular geological periods. It has been remarked ‡ that there is a certain analogy or proportion between the geographical and the geological distribution of organized beings. Now there are very few instances in which the *genera* of recent Ferns have a strictly limited geographical area: scarcely any genus (excepting those which consist of only one or two species) is confined to a single geographical province or region§. Very many even of the *species* of Ferns (as has been amply shown by Sir W. Hooker and by Dr. Joseph Hooker) have a wide geographical range. With the *genera* this holds good in the majority of cases; and the instances are numberless in which we find nearly allied or representative species in distant countries. It appears therefore to a certain

* Introductory Essay on Flora of Australia, p. 100, 101.

† By the *Indian* fossil flora in this memoir I always mean that of the supposed Jurassic beds of Nágpur, of the Rájmahál Hills, and of the Burdwan coal-field. By the *Australian* fossil flora, I mean that of the coal-formation of New South Wales.

‡ By Edward Forbes and others,

§ See what is said on this point by Mr. John Smith, Hooker's Journal of Botany, vol iv.

degree probable that the *generic* forms of Ferns may have had a wide range in time also, and that allied (though not identical) species may have existed in very different ages. I do not wish to lay much stress on this argument; but it may suggest a certain degree of caution. The genus *Phyllotheca* affords more decided evidence of Jurassic affinities in the fossil flora of the Indian and Australian coal-fields, since the only known species *out* of those coal-fields have been discovered by M. de Zigno in an undoubtedly Jurassic formation in Northern Italy*. The other vegetable remains of the deposit we are considering are too uncertain in their nature and affinities, or too remote from any known in Europe, to afford any help towards determining the question of age.

On the other hand, there is in the Nágpur collection a striking deficiency of the *Cycadeæ* (*Pterophyllum*, *Zamites*, *Otozamites*, and the like), a family very characteristic of the Jurassic flora in Europe. This deficiency does not extend to the plant-bearing deposits of Bengal. Dr. McClelland describes several well-marked *Cycadeæ* from the Burdwan coal-fields. In a set of drawings, which I have examined, of fossil plants procured by Prof. Oldham from the Rájmahál Hills, as many as nine out of thirteen forms represented are undoubted and well-characterized Cycads. In the Australian coal-fields, again, I have no evidence that any Cycads have been found. The question may therefore arise, are the fossil plants of Nágpur contemporaneous with those of Australia, and of a *different* age from the Burdwan and Rájmahál deposits? But the *Glossopteris Browniana* appears to be common to the Australian and Bengal coal-fields†; so also is the very peculiar and characteristic form called *Vertebraria*. I think, therefore, that the several plant-bearing deposits of which I have been speaking, cannot well be separated geologically, and that, as far as the evidence derived from fossil plants can be trusted‡, there is a strong probability that they are all of Jurassic, or at least of Mesozoic age.

4. The fossil flora described in this paper appears fully as different from the existing vegetation of India, as the fossil flora of our Jurassic or our Carboniferous rocks is from the existing vegetation of Europe. Drs. Hooker and Thomson, in their admirable Introduction to the 'Flora Indica,' have shown us what are the characteristic families, genera, and species of plants in the different districts of India; and in none of these districts do we find anything resembling the fossil vegetation of Nágpur. The predominance of Ferns, the absence of any certain indication of ordinary (angiospermous) Exogens, the absence of Palms, and, in fact, the apparent absence of all those families and genera of plants which can be considered in any way characteristic of the Indian flora, strikingly distinguish this extinct vegetation from that of the present day. If it were contemporaneous with our Jurassic flora, it cannot be denied

* De Zigno, Fl. Foss. Form. Ool., pp. 59, 60.

† Brongniart, Hist. Vég. Foss.; McCoy; Morris in Strzelecki's New South Wales.

‡ To what extent evidence of this sort can be trusted must remain doubtful until the *Petit-Cœur* mystery shall be solved.

that the vegetation of India was in those ages much more similar to that of Europe than it is now.

The absence of Palms from a deposit representing to us the vegetation of an Indian district is the more striking, because both the leaves and the seeds of those plants are of a very durable nature, and likely to be preserved. In the Bengal coal-field, indeed, is found a *Zeugophyllites*, which Prof. Brongniart appears to consider as an undoubted Palm; but I can find no trace of it in the Nágpur collection.

Postscript.—Since this paper was thus far completed, I have received Professor Oldham's memoir* on the geological relations of the rocks of Bengal and Central India, which throws some new and important light on the subjects I have been discussing. Accordingly I find it necessary to correct in some points the opinions as to the geological age of these fossil plants, which I have above expressed. Prof. Oldham shows that the group of rocks of the *Rájmahál* Hills constitute a formation quite distinct from that of the coal-bearing beds of Burdwan and some other localities; to which latter group he applies the name of the *Damuda* beds. He shows that the fossil vegetation of the two formations is entirely different, both specifically and in general aspect; that *not one* species is common to the two; that the Rájmahál beds are characterized by a remarkable abundance and variety of *Cycadeæ*, by a comparative paucity of Ferns, and by the absence, in particular, of the genus *Glossopteris*, as well as of *Phyllotheca* and *Vertebraria*; while the Burdwan or Damuda beds are characterized especially by *Glossopteris*, *Phyllotheca*, and *Vertebraria*, with scarcely a trace of Cycads. It is evident that the Nágpur fossil flora agrees altogether in these respects with that of the Damuda, and not with that of the Rájmahál formation. Prof. Oldham is of opinion that the Rájmahál beds are *mesozoic*, and probably Jurassic—the Damuda beds *palæozoic*. On this latter point I am not entirely prepared to go along with him. I still think, for the reasons already given, that the *facies* of this Nágpur and Burdwan flora is rather mesozoic. But this is a point by no means clear, and one on which much further light is yet required before we can come to a safe conclusion. The palæobotanical evidence is far from unequivocal, and, such as it is, might be outweighed by the discovery of a single well-marked and thoroughly characteristic fish, shell, or coral.

I perceive that Prof. Oldham has come to the same conclusion touching the so-called *Vertebrariæ* in general at which I had already arrived in relation to those of the Nágpur collection; namely, that they were *roots*. As he observes, they seem to have played a somewhat similar part, in the Bengal coal-field, to that of the *Stigmariæ* in the coal-fields of Europe and America.

* Memoirs of the Geological Survey of India, vol. ii. part 2. 1860.

DESCRIPTION OF PLATES VIII.–XII.

Plate VIII.

Fig. 1. Glossopteris Browniana, *var.* Indica, *Ad. Brongn.* An imperfect frond.
Fig. 2. ———. Apex of a frond.
Fig. 3. ———. Base of a frond.
Fig. 4. ———. Enlarged portion of a frond, showing the venation and sori.
} From Silewá*dá*.
Fig. 5. Glossopteris Browniana, *var.* Australasica, *Ad. Brongn.* From the foot of the Mahádewa Hills.
Fig. 6. Glossopteris musæfolia, *C. B.* An imperfect frond. From Silewá*dá*.

Plate IX.

Figs, 1–3. Glossopteris leptoneura, *C.B.* From Kámpti.
Fig. 4. ——. Portion of frond, magnified.
Fig. 5. Glossopteris stricta, *C.B.* From Silewá*dá*. Reduced ¼th.
Fig. 6. Pecopteris?
Fig. 7. ——— } Parts of a frond.
Fig. 8. ——— Enlarged leaflets.
} From Kámpti.

Plate X.

Fig. 1. Cladophlebis? Portion of a frond. From Kámpti.
Fig. 2. Tæniopteris danæoides (?), *McClell.* Portion of a frond. From Kámpti.
Fig. 3. Filicites (Glossopteris?). Imperfect frond. From Silewá*dá*.
Fig. 4. Filicites (Glossopteris?). Imperfect frond. From Kampti.
Fig. 5. Nœggerathia? (Cyclopteris? Hislopii, *C.B.*). Imperfect leaf. From Bharatwá*dá*.
Figs. 6–9. Phyllotheca Indica, *C.B.* Portions of stems. From Bharatwá*dá*, Silewá*dá*, &c.

Plate XI.

Fig. 1. Phyllotheca Indica, *C.B.*
Fig. 2. ———————.
} Portions of stems. From Bharatwá*dá*.
Fig. 3. Roots of Phyllotheca? From Kámpti.

Plate XII.

Fig. 1. Knorria? (Portion of stem of a Conifer?). From Mángali.
Fig. 2. Stigmaria? (Portion of the rhizome of a Fern?). From Mángali.
Fig. 3. Portion of a stem with a large scar. From Silewá*dá*.
Fig. 4. Yuccites? Imperfect leaf. Reduced. From Kámpti.

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2. *On the* Age *of the* Fossiliferous Thin-bedded Sandstone *and* Coal *of the* Province *of* Nágpur, India. By the Rev. Stephen Hislop.

(Communicated by the President.)

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2. Barkoi and the foot of the Mahádewa Hills.
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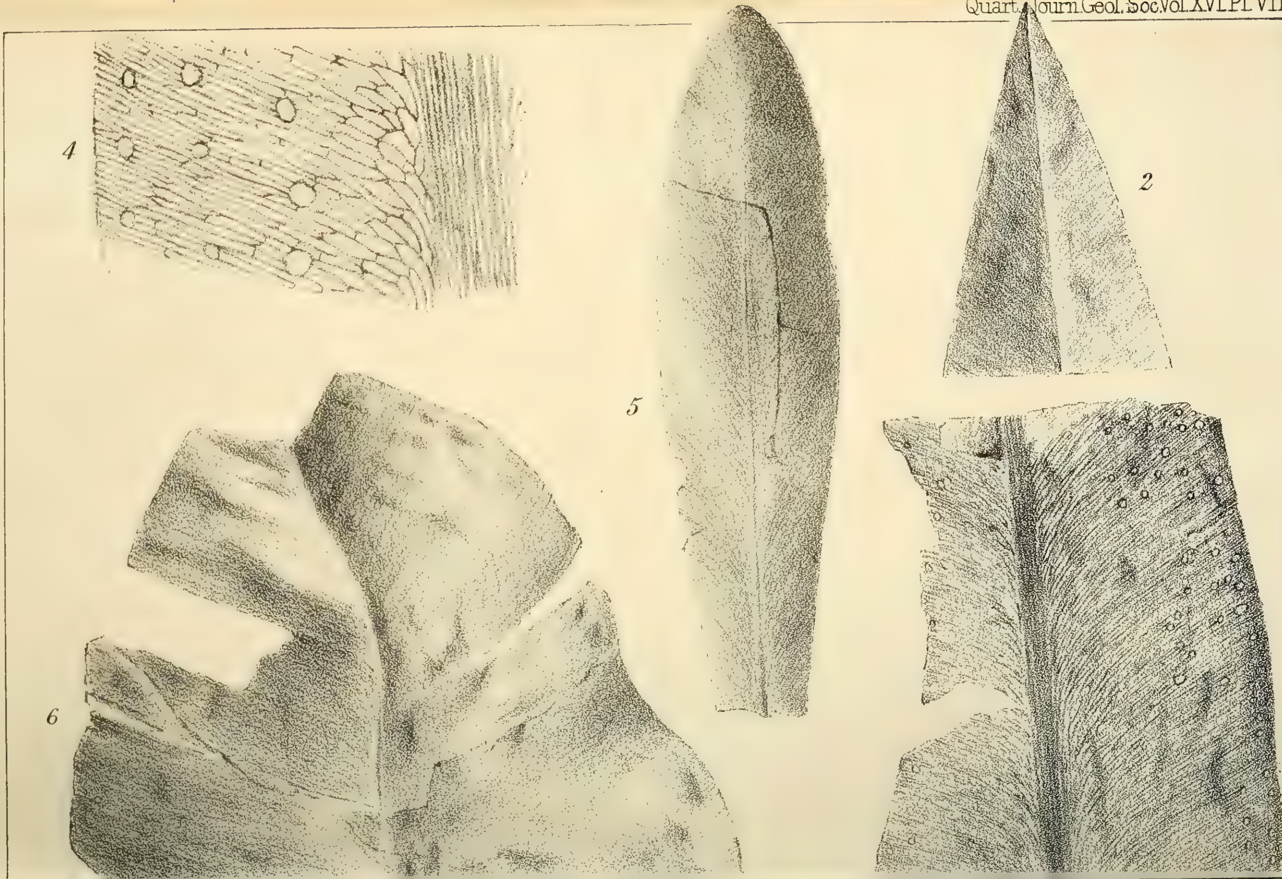
   (1.) Fossil flora of New South Wales.
   (2.) Fossils of the Indian Plant-bearing Sandstones and Coal-fields.
      A. Plant-remains.
      B. Animal-remains.

1. *Nágpur Circle.*—If with a radius of 14 miles a circle be drawn around the city of Nágpur, it will include within its northern half Kámpti, Bokhára, Silewá*dá*, Tondakheiri, Bábulkhe*d*a, and Bharatwá*dá*; but it will leave out Arajmet, which lies 20 miles west of



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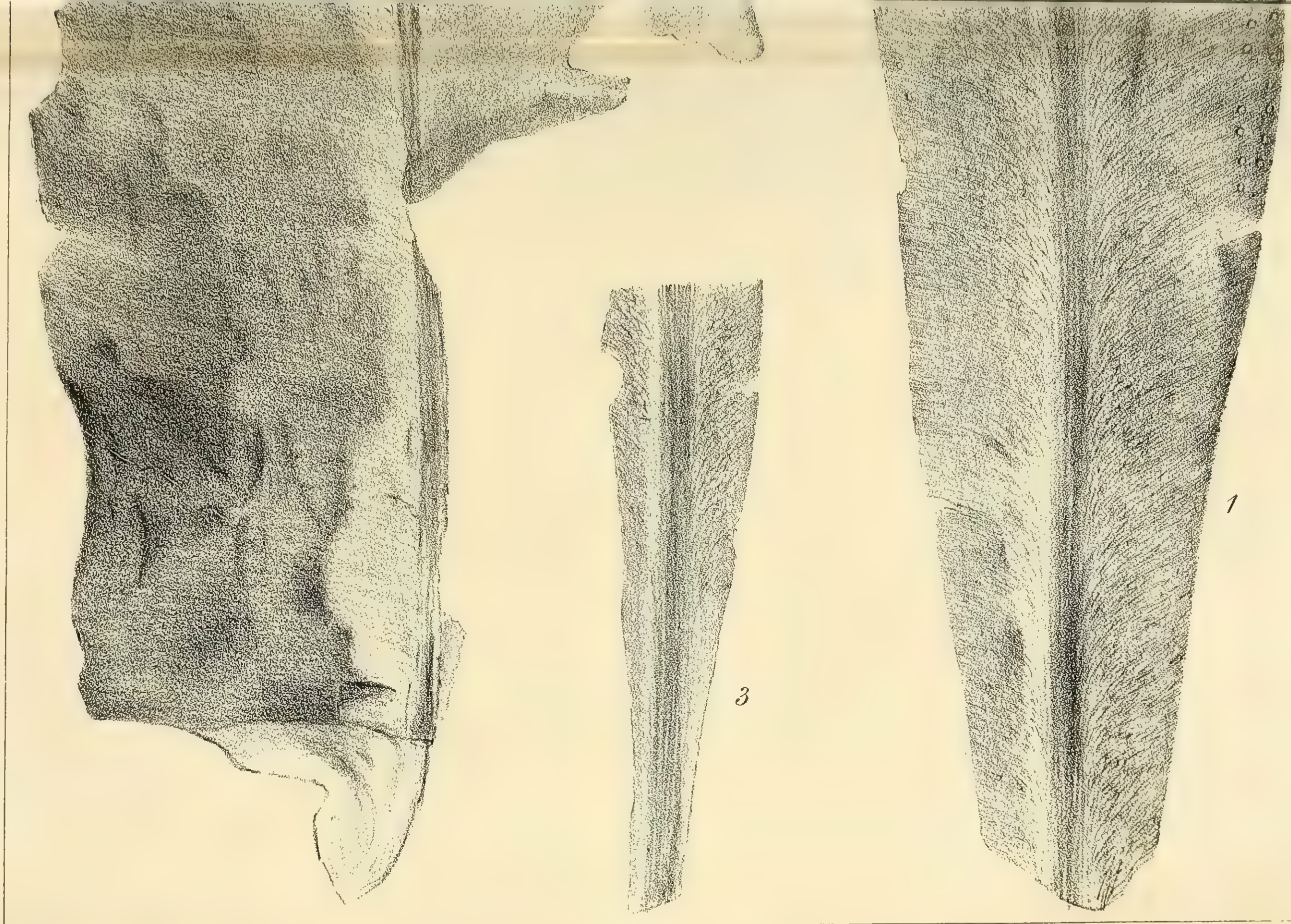

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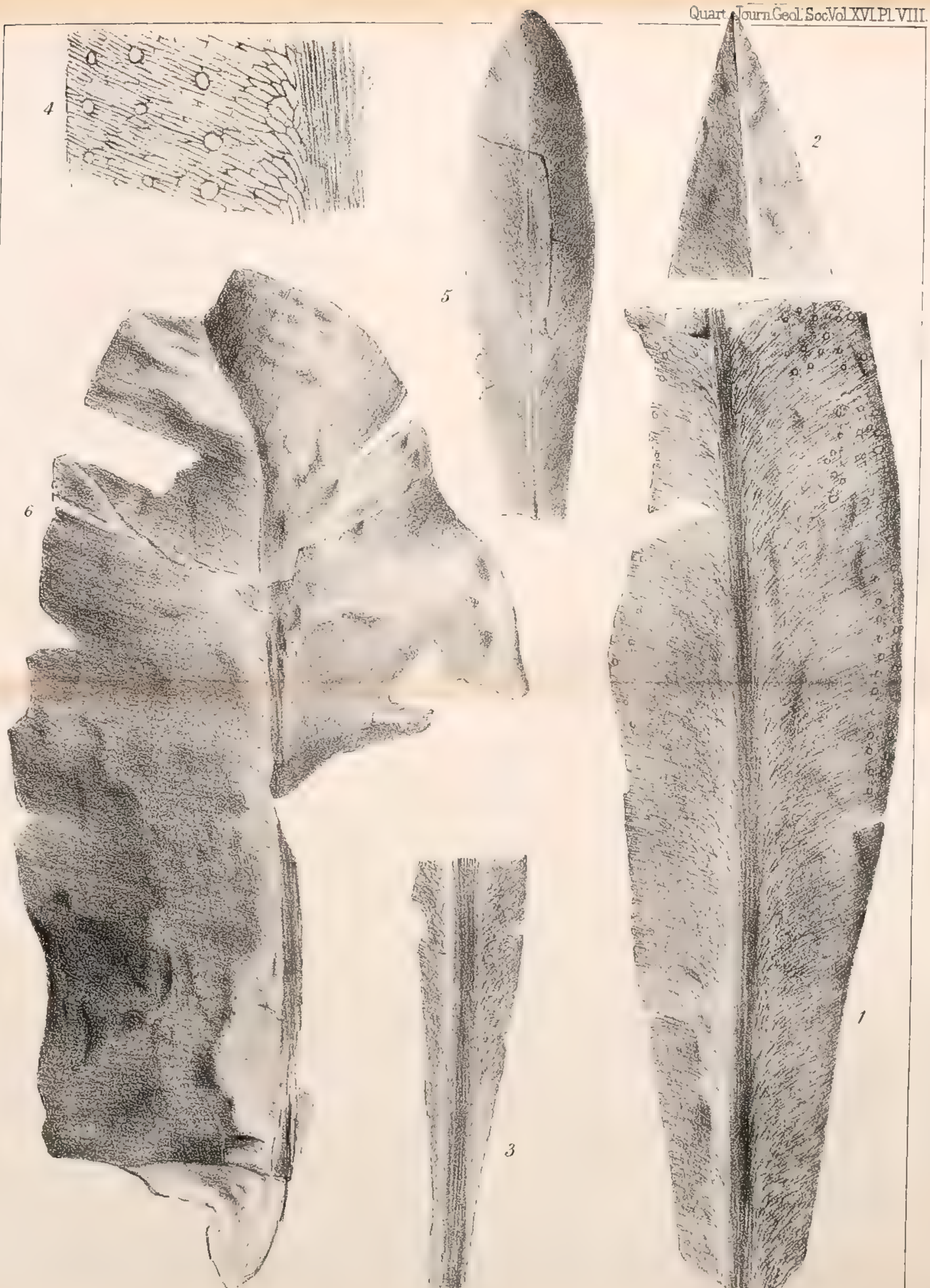
FOSSIL PLANTS FROM CENTRAL INDIA.



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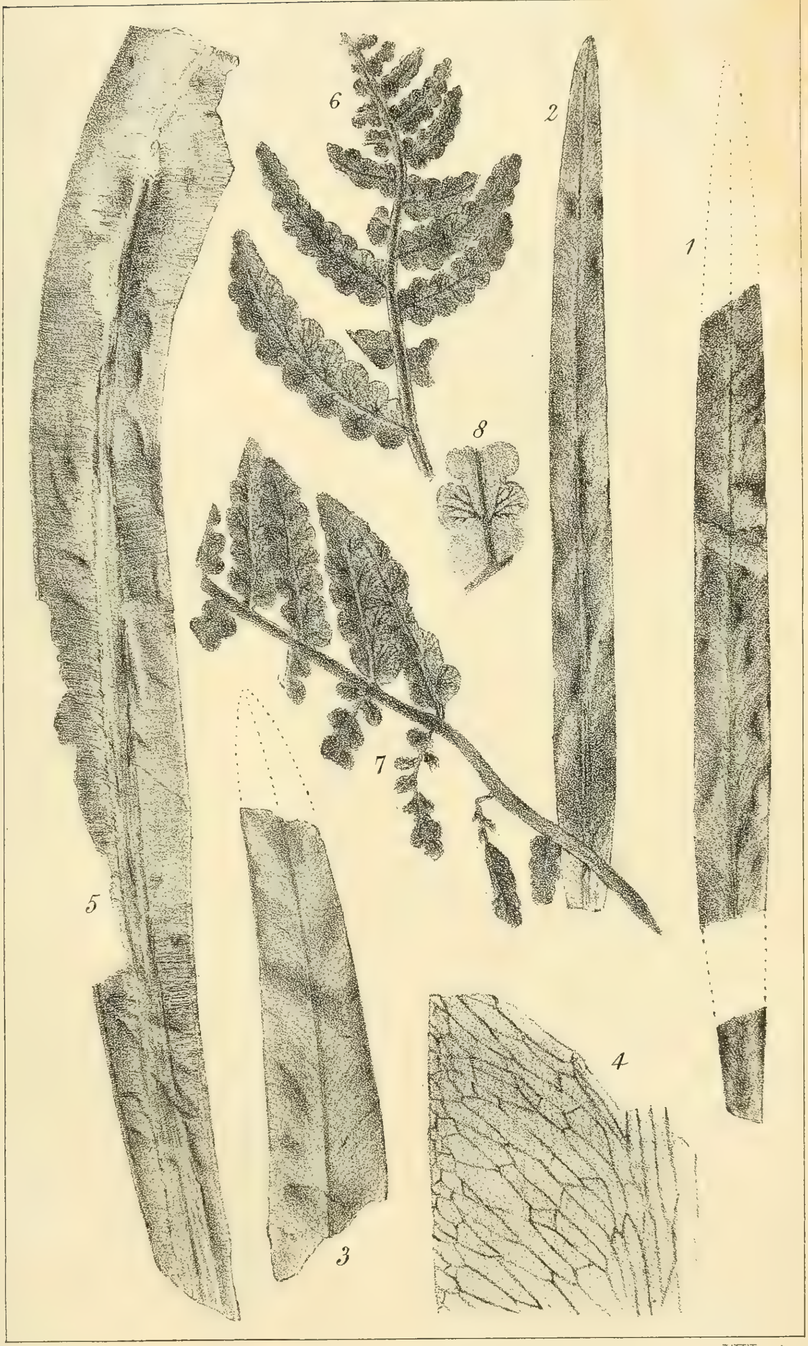

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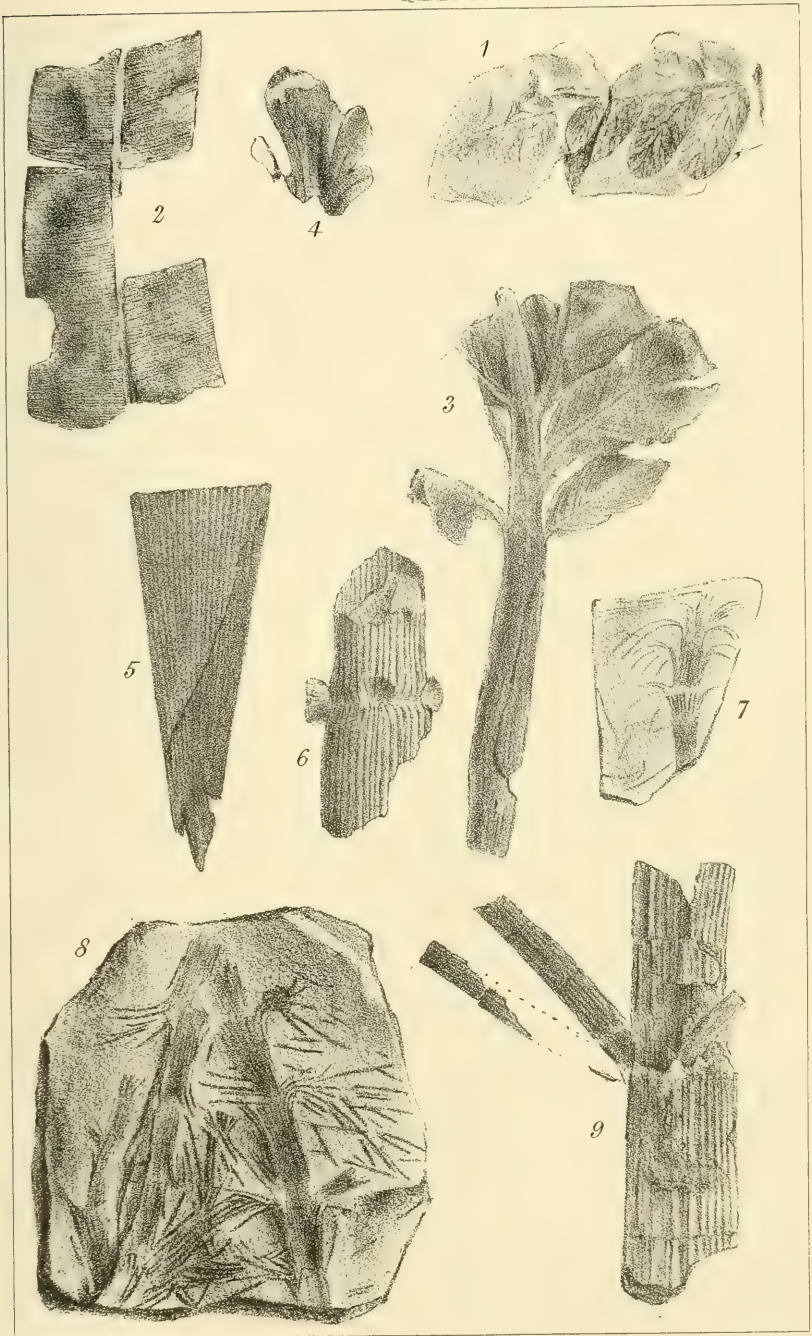

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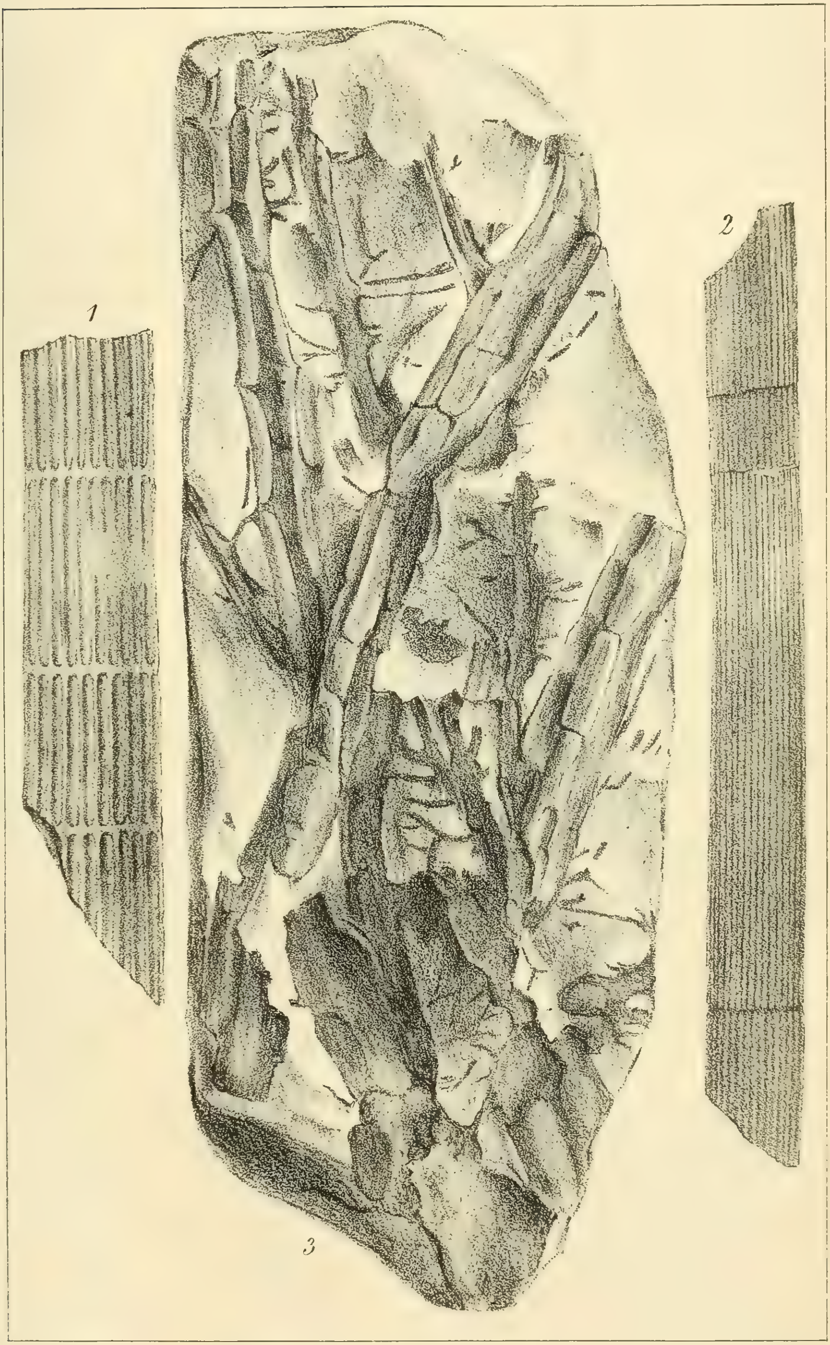

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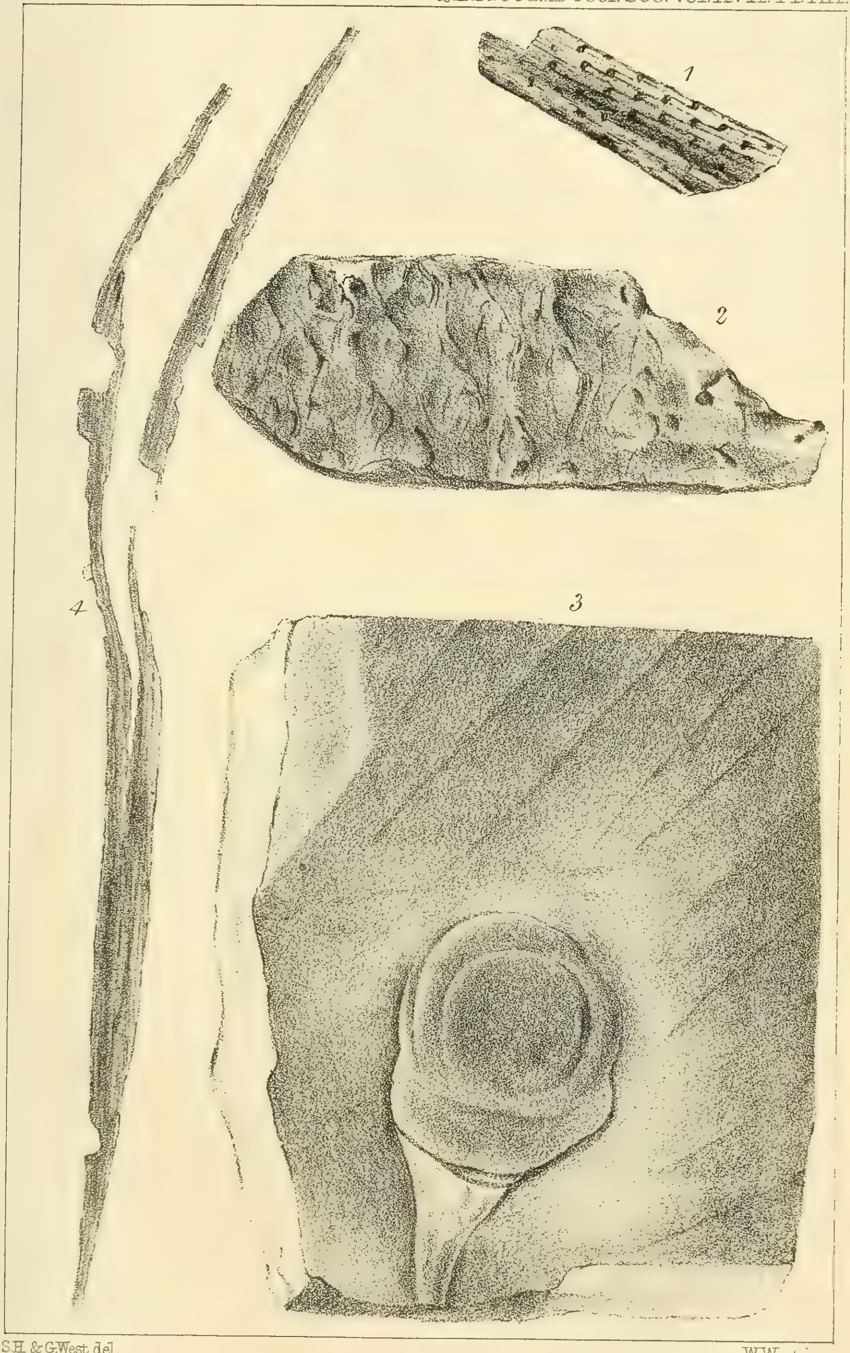
W. West imp.

FOSSIL PLANTS FROM CENTRAL INDIA.



S.H. & G. West del.

W. West imp.

FOSSIL PLANTS FROM CENTRAL INDIA.

Nágpur, and Chorkheiri, which is 35 miles to the north-east, while Chándá is situated 85 miles to the south. At all these places the thin-bedded sandstone with vegetable remains is the same, as it presents the same appearances both palæontological and lithological.

2. *Barkoi and Mahádewa Hills.*—That this thin-bedded sandstone is identical with the coal-shale at Little Barkoi, near Umret, and at the base of the Mahádewa Hills, in the N.N.W. part of Nágpur province, I have ascertained by personal inspection, and have endeavoured to prove in the Quart. Journ. Geol. Soc., vol. xi. p. 555. At all the localities already named, arenaceous as well as carbonaceous, there is a similar group of fossils; and at Bokhárá, an acknowledged site of the plant-sandstone, there is a tendency among the strata, which are usually white, to become brown and carbonaceous through the abundance of their comminuted vegetable matter.

3. *Western Bengal.*—That the plant-sandstone and carbonaceous beds of Nágpur are of the same age as the coal-strata of Western Bengal, I have attempted to show in the 'Quart. Journ. Geol. Soc.' *loc. cit.* The rocks of both provinces have embedded the same flora, including species of *Pecopteris, Glossopteris,* and *Tæniopteris, Vertebraria Indica**, *Trizygia* (or *Sphenophyllum*) *speciosa,* a species of *Phyllotheca,* and a stem, which McClelland has erroneously named *Poacites muricata.* Many more points of resemblance, I have no doubt, will be discovered when the Bengal strata shall have been more carefully examined.

4. *Mángali.*—Thus far I may calculate on a general concurrence in my conclusions; but, when I embrace in this comparison some thin-bedded, red, argillaceous sandstone at Mángali and Mesá, about 60 miles south of Nágpur, difficulties arise, and a difference of opinion has been expressed. In a Report on the Talchee Coal-field, by Messrs. Blanford and Theobald, the authors seem disposed to place the Mángali beds above the plant-sandstone and coal; and, as they consider the former Permian, the two latter they regard as at least of that age†. It must be admitted there is some apparent ground for this view. The strata within the semicircle north of Nágpur, and at the other localities mentioned in paragraph 1, are of a whitish hue; those at Mángali are of a brick-red colour. In the former the fossils, with the exception of an Insect's wing found at Kámpti, are exclusively vegetable; in the latter they are chiefly animal. In the one Ferns abound, in the other not one has hitherto been discovered; but, instead of them, we have the reptilian *Brachyops laticeps* (Owen), an undescribed species (if not two) of the crustacean *Estheria,* and the jaws and scales of ganoid Fishes. Yet this distinction in colour and fossil contents most probably depends on a difference, not of time, but of local condition; for, with all the dissimilarity, there are numerous points of agreement. The strata near Nágpur and Chándá, and those at Mángali, intermediate between these two places, though differing in

* *Vertebraria* and *Trizygia* are not recognized in the preceding paper by Sir C. Bunbury as occurring in the plant-bearing sandstones of Nágpur.—Editor.

† Mem. Geol. Surv. of India, vol. i. pt. 1, p. 82.

colour, are alike in many other respects. Both are thin-bedded and argillo-arenaceous, and, after continuing so for about 15 feet, they both pass into a coarser whitish sandstone below; and though the fossils are so diverse in their general character, and though many vegetable remains found near Nágpur and Chándá are wanting at Mángali, yet the fossil plants that do occur in the latter neighbourhood are on the whole similar to those in the former. Thus at Mesá there is a seed or seed-vessel about $\frac{2}{3}$ in. long, and $\frac{1}{3}$ in. broad, resembling a paper kite in form. This also occurs of the very same dimensions and shape at Kámpti. Again, a smaller fossil of a similar kind is common to the beds at Mesá and Bharatwá*d*á. Further, a small piece of stem from Mángali, with distant lanceolate scars running along it, is the miniature of a larger branch from Kámpti. And, lastly, Mángali furnishes various sulcated jointed stems, which, as far as the state of their preservation warrants a judgment, resemble stems abundant at Kámpti, Silewá*d*á, Bharatwá*d*á, &c. This amount of agreement, apparently specific, between the fossils from Mángali and from the vicinity of Nágpur, is sufficient, in my opinion, to authorize the inference that the strata containing them are nearly, if not exactly, on the same geological horizon.

5. *Kotá on the Pranhítá.*—And now, as I have pointed out the connexion between our Nágpur plant-strata and those of Bengal, so with the addition of the Mángali beds and their animal remains, I may institute a comparison between them and the rocks at Kotá, on the Pranhítá. There, under a great thickness of coarse iron-banded sandstones, developed in the neighbouring hills, we have thin-bedded strata abounding, as at Mángali, in animal remains, including *Lepidotus Deccanensis*, *L. longiceps*, *L. breviceps*, and *Œchmodus Egertoni*. In addition to these ganoid Fishes obtained by the late Drs. Walker and Bell, I have procured from the same locality the exuviæ of Insects and *Entomostraca*, among which there are *Cypridæ* and a species of *Estheria* determined, on the authority of Mr. Rupert Jones, to be identical with the larger form at Mángali. With this connecting link between the two series of rocks, the presumption is that they are of the same age. The vegetable remains at Kotá seem to consist principally of stems, but in such an imperfect state of preservation as to be wholly unrecognizable. Dr. Bell, however, in a layer of sandstone only 6 feet below the ichthyolitic bituminous shale, discovered impressions of "leaves," which (although he was disposed to consider them dicotyledonous) belonged to a genus with simple entire fronds and anastomosing venation; and I conceive myself justified in believing them to have been acrogenous, and belonging to a species of *Glossopteris*. The arenaceous stratum containing them is obviously part of the same series as the bituminous shale, with which it alternates, there being as much of the shale below as above the sandstone. Now, as from the existence of a species of *Estheria* common to the rocks at Mángali and Kotá, we inferred their contemporaneousness, so from the discovery of what appears to be a species of *Glossopteris* at Kotá, we are led to the conclusion that the rocks there are connected in age with those near Nágpur,

in which that genus abounds: and this comparison of the strata at Kotá, first with those at Mángali and then with those near Nágpur, confirms the evidence which I have already adduced of the close relation between the Mángali and Nágpur beds.

Dr. Bell's shaft, which has furnished me with most of my information regarding the succession of strata at Kotá, ended in a deposit of red clay lying 73 feet below the bituminous shale with Fish-remains. Can this be the red clay which is found at Málec*di*, 30 miles N.N.W. of Kotá, to embed coprolites and several forms of *Ceratodus* teeth, which have been described by Dr. Oldham in a recent publication of the Indian Geological Survey?

6. *Rájmahál Hills.*—How the upper beds of the Rájmahál Hills stand related to the strata that have engaged our attention, and whether there are any examples of them in the Nágpur province, are questions which meet us here. It is obvious that some interval elapsed between the deposition of the inferior and superior beds at Rájmahál. How great, then, was that interval? To me it appears not to exceed the space of time requisite for a whole formation; as the floras of the respective periods, though different, are not so distinct as to indicate a decided change in the circumstances of their growth. In both we have *Tœniopteris* and the *Cycadaceæ,* the latter being represented in the lower strata of Bengal by *Zamites Burdwanensis,* and in the higher by several species and genera. The equivalents of the upper Rájmahál beds have been met with by Mr. H. B. Medlicott, on the Hurd River, a little south of the Narbaddá*. This discovery brings the existence of these rocks very near our province, but hitherto they have not been found within its limits. It is possible that some of the vegetable impressions occurring at Kámpti, especially one or two species of *Tœniopteris,* are originally from this source; for most of the fossil plants there are not found *in situ,* but in blocks dispersed through the coarse iron-banded sandstone. There can however, I think, be no doubt that the greater portion of these remains are the same as others still in their original position in the laminated sandstone of the neighbourhood; and even to the hypothesis that the remainder may belong to a younger group of strata, there is this objection, though only of a negative kind, that at Kámpti, so far as known, there is a total absence of the *Cycadaceæ* which characterize the upper beds of Rájmahál.

7. *Comparison of the Strata and Fossils of Nágpur, Barkoi and the Máladewas, Mángali, and Kotá.*—Setting, then, this higher series at Rájmahál and the Hurd River in a category by itself, let us endeavour, by a comparison with formations out of India, to determine the age of the rocks near Nágpur, at Barkoi and the Mahádewas, in Western Bengal, and at Mángali and Kotá, all of which we have seen to be almost, if not altogether, contemporaneous.

(1.) *Fossil Flora of New South Wales.*—There are certain deposits in New South Wales which, it must be acknowledged, present obvious features of resemblance to the Indian strata under consideration. The connexion between those beds in Australia and ours in

* Indian Records, x. p. 17.

India consists in the occurrence in both of the genus *Pecopteris, Sphenopteris, Glossopteris, Phyllotheca*, and *Vertebraria*; a leaf which is figured in Strzelecki's 'Physical Description of New South Wales' under the name of *Zeugophyllites*; and a large seed or seed-vessel, of which there is an Australian specimen in the British Museum. In regard to the genus *Glossopteris*, the resemblance between some of the specimens from India and others from Australia is so close as to lead to the belief that the species are either nearly allied or identical. The same may be said of the genus *Vertebraria**, the leaf, and the seed or seed-vessel above referred to; while there is a general similarity of form in *Pecopteris, Sphenopteris*, and *Phyllotheca*. At first sight the vegetable remains which I have enumerated might be regarded as palæozoic, seeing they are found in strata which in Australia are said to alternate with beds containing Mollusks of a Carboniferous or even Devonian aspect; but as the localities where these shells occur are far from affording a complete series of formations for comparison with those of other countries, their precise age cannot in the mean time be ascertained. The southern hemisphere seems to be the only part of the world in which we meet with such a combination of plants and quasi-carboniferous or quasi-devonian shells; and since in other districts plants similar to most of them are common, along with animal remains that are evidently not palæozoic, we are reduced to the necessity of supposing either that shells apparently palæozoic survived in Australia to mesozoic times, or that plants which in other places flourished at a comparatively late period were introduced on the stage of being there at an earlier epoch. Perhaps it will be found that the Mollusks and Plants at our antipodes met each other half-way; for while there is a great resemblance in the floras of the Indian and Australian geological fields which we have been comparing, and while, on the whole, they exhibit a Lower Jurassic *facies*, yet some plants that are most characteristic of the Jura formation are wanting in New South Wales, though frequent in India—I refer to *Tæniopteris* and *Zamites*. But this is mere conjecture. It must be confessed that the whole subject of these fossils from the Newcastle and Hawkesbury basins is involved in obscurity. Still that obscurity, resting on isolated spots with a very limited succession of rocks, ought not to prevent us from receiving light from other parts of the world, where the stratigraphical series is much better developed, and the relations of its various members indisputably fixed.

(2.) *Fossils of the Indian Plant-bearing Sandstones and Coal-fields.*—To the consideration of these better-known localities let us now proceed.

A. *Plant-remains.*—Among our Indian plants a very marked feature is the abundance of simple-fronded Ferns. This of itself, as it appears to me, would favour the supposition that the rocks in which they occur are of Jurassic age, as it is in strata of that period that simple-fronded Ferns are most numerous in Europe. But the inference becomes still more probable when we advert to the parti-

* See the remarks on *Vertebraria* in the preceding paper, *supra* p. 339.—Edit.

cular genera of these Ferns. The most common is *Glossopteris*. This is not at present looked on as a European genus; but having had an opportunity, through the kindness of Professor Allman, of inspecting the plants collected by the late Hugh Miller at Helmsdale, and now deposited in the Museum of Edinburgh University, I see no reason to doubt its occurrence in the Oolite of Sutherlandshire. Most of the specimens that I examined, I am aware, are probably only detached portions of the compound frond of *Sagenopteris*; but there are others, such as those marked "48" and "104," which seem too large to be so regarded. Besides, some (*e. g.* No. 54) are furnished with one or two specks that bear a striking resemblance to the punctiform *sori* of a true *Glossopteris*. At Bayreuth also there are single fronds, which differ in size and form from *Sagenopteris*, and agree much more in these respects with our Indian genus. If, therefore, the Lower Jura of Bayreuth and the Oolitic beds of Helmsdale do indeed yield *Glossopteris*, then the presumption is that, seeing this genus, like its nearest ally among the compound-fronded Ferns, is confined in Europe to the Jura, our eastern rocks containing it belong also to that formation.

A similar conclusion may be deduced from the abundance in India of the genus *Tæniopteris*. If all the specimens found in the blocks at Kámpti are from the inferior beds, there would seem to be three species from these rocks in our province, one of them being from the carbonaceous strata at Barkoi *in situ*. Now this genus, with the exception of two or three species, is never found at a lower level than the Trias, and it even ranges as high as the Wealden. It reached its *maximum*, however, as is well known, in the Jura. One of the species common in the Kámpti boulders bears the closest affinity in shape, size, and venation to *Tæniopteris magnifolia* of Prof. W. B. Rogers, from the lower Jurassic strata of Eastern Virginia.

The same relation to European Ferns of Jurassic age is borne by our compound-fronded genera. One species of *Pecopteris* from Kámpti seems to me to resemble *P. Haiburnensis* from the Lower Oolite of Scarborough, more than any older form. Again, we have from Kámpti a tripinnate frond with bifurcate venation, but without a central midrib, which differs from any genus, so far as I know, that has yet been *described*. A similar Fern, however, without a name, has been *figured* by Baron de Zigno from the Lower Jurassic beds of Northern Italy.

In the province of Nágpur we have hitherto met with no decided *Cycadaceæ*. But the contemporaneous coal-basin of Ráni-ganj, according to McClelland, presents us with a species which he has named *Zamia Burdwanensis*. Few members of this family have yet been discovered under the Jurassic formation. At Kámpti there has been found a portion of a leaf, apparently lanceolate, with fifteen somewhat parallel veins, which in a preceding part of this paper I have identified with the *Zeugophyllites* of New South Wales. This name has been changed by Schimper and Mougeot for *Schizoneura*; but in my opinion the *Schizoneura* of these authors is not the same as the leaves of New South Wales and Kámpti. The plant figured from the *Grès bigarré* of the European continent appears to have possessed narrow leaves arranged in a verticel; but our leaf and that from Australia are broader, and agree better with the pinnæ of a plant from Burdwan, which is now in the British Museum. In that fossil the pinnæ resemble those of the larger specimens of *Zamites distans,* only they are opposite, and not alternate as in Sternberg's species. If I mistake not, its pinnæ are characterized by 14–16 sub-parallel veins, like our imperfect specimen. If it is not to be classed with *Zamites,* to which it bears an obvious affinity, I think the old name of *Zeugophyllites* should be continued for it as the most appropriate.

The *stems* in our collection present peculiar difficulties. But it is something to know that none of them belong to the *Calamites* of the true Carboniferous series. Those that have been taken for such appear chiefly to belong to the genus *Phyllotheca*, which has recently been discovered by De Zigno in the Lower Oolite of the Venetian Alps. I am persuaded that, were the foliage of the sulcated stems from Eastern Virginia obtained, some of them which agree in all respects with our leafless stems of *Phyllotheca** would be ascertained to belong to this genus, which so abounds in the rocks of New South Wales, India, and Northern Italy. Another of our stems, not furrowed however, but ribbed, which was found by my friend Mr. Hunter at Silewádá, and is distinguished by its deciduous disks near the joint, is evidently related to the *Equisetites lateralis* from the Oolite of Scarborough. At Mángali there occur two stems, which, if I may judge from description alone, resemble two met with in the Virginian coal-field; one apparently being a *Knorria*, and the other probably having some connexion with the fossil which Sir C. J. Bunbury compares with *Sigillaria* or *Aspidiaria Menardi*†.

In speaking of some reticulated, simple, entire leaves brought to light by Dr. Bell, I have ventured to suggest that they were most probably fronds of Ferns, as dicotyledonous leaves of that form are not known below the Eocene. I am inclined, however, to believe that exogenous plants did exist at the period in question. At Silewádá there is an abundance of stems of considerable size, which have lost their woody structure, but seem to have possessed bark striated obliquely upwards from left to right. In addition to this external marking, most of our specimens exhibit the cicatrices of leaves, and in one case there is a round sprouting bud left after the foot-stalk has fallen off. Some of the scars are longitudinal, others are transverse, but all are sparsely distributed over the stem. The transverse scars slightly resemble those left on the trunk of the Papaw (*Carica Papaya*). If the resemblance were to hold good also as to the soft nature of the wood, we could easily understand how it is that the trees now referred to present to us nothing but the bark. But, whether those bearing merely scars are to be ranked as exogens or not, I must submit, with all deference, that the stem with the round bud belongs to that division of the vegetable kingdom. And if so, it would add to the proof which I have brought forward, that the

* e. g. *Calamites planicostatus*, Trans. Amer. Geol. Soc. 1840–2.

† Quart. Journ. Geol. Soc., vol. iii. p. 286.

plant-bearing beds are not very low in the Mesozoic series. These stems belong to genera seemingly altogether undescribed. The only fossil that has fallen under my observation which admits of being compared with them, is one figured by Professor Hitchcock in his paper on the Sandstone Formation of Connecticut and Massachusetts*, which has been shown by Prof. W. B. Rogers to be nearly on the same horizon as the Richmond coal-basin. The object there represented, as Sir C. Lyell justly remarks, cannot be a *Tæniopteris*, but it may very well be a compressed branch or trunk of a tree, on which supposition the oblique lines from left to right would correspond with the markings on the bark of our Silewádá stems.

Before leaving this part of my subject, I would remark that some of our seeds or seed-vessels remind me of some that occur in the Lower Oolite at Stonesfield along with *Tæniopteris*.

B. *Animal-remains*.—Turning now to the animal-remains, we find that, like our plants, they are best represented in rocks of the Mesozoic epoch.

When I transmitted the cranium of *Brachyops laticeps* to your Society in 1853, I pointed out its relations to the *Labyrinthodontidæ*, which had never before been recognized in the East, and attempted also to indicate the section of the family to which it belonged. To me it seemed to have little connexion with the *Archegosaurus*, &c., but to be allied to that division of Reptiles which Von Meyer has named *Prosthophthalmi*, and to approach most nearly the genus *Metopias*. Professor Owen in his description did not enter on this part of the subject; but I am glad to perceive that Professor Huxley has since had occasion to allude to it, while speaking of the remains of two Reptiles from South Africa and Australia, and, without knowing that it had been done before, has shown a relationship to exist between the Mángali *Brachyops* and the *Metopias* of the Keuper†. We are thus authoritatively furnished with a means of judging of the era of our Labyrinthodont, which proves to be the division of the Trias nearest to the Jurassic formation.

Together with the *Brachyops* skull, there occurs at Mángali a great abundance of an *Entomostracon*, which, in accordance with a suggestion from my friends Drs. Leith and Carter, I was disposed in 1854 to call *Limnadia*, but which Mr. Rupert Jones prefers to class with *Estheria*. This species, which is almost equally common at Kotá and Mángali, is somewhat similar to that found in Virginia; but it perhaps still more nearly resembles in form and ornamentation the species that sports in the pools of Central India at the present day, and which a few months ago was described and figured by Dr. Baird as *E. compressa*‡. Besides *Estheria* we have another genus of *Entomostraca* at Kotá—I mean *Cypris*. From its elongate form Mr. Jones feels warranted in saying that, according to our present know-

* Plate 14. fig. 2, Trans. Amer. Geol. Soc. 1840–2.

† Quart. Journ. Geol. Soc., vol. xv. p. 647. Prof. Huxley here speaks of the affinity between *Micropholis* and *Metopias*, and subsequently of the resemblance that *Micropholis* bears to *Brachyops*.

‡ Zool. Soc. Proceed., vol. for 1860, p. 188.

ledge, we should not know where to look for its analogue in rocks older than the Lower Jura or Upper Trias.

In the same limestone as contains these *Entomostraca* at Kotá, we are presented with an interesting assortment of Insect exuviæ, including the wing-covers of *Blattidæ* and the elytra of Beetles, which forcibly remind me of the researches of the Rev. P. B. Brodie in the Lower Jura of England. The Fishes of this limestone and its associated bituminous shale have been pronounced by Sir P. G. Egerton to belong to a "true Oolitic form, and apparently of the date of the Lias*". Finally, an imperfect bivalve found in the shale with *Lepidotus Deccanensis* exhibits an appearance of corrugation at the umbo such as characterizes the genus *Unio*, a Mollusk of comparatively recent introduction on the stage of existence.

Combining these results, it would appear that of the rocks which we have been comparing, while one fossil (viz. the *Brachyops* of Mángali) points to the highest member of the Trias, and while the abundance of *Estheriæ* associated with it would indicate either that or a Lower Jurassic age, the latter organism is found at Kotá, with Fishes, Insects, *Cypris*, and *Unio* (?), which are all in favour of an epoch not lower than the Lias. And to this same side of the balance must be added the evidence of *Glossopteris*, *Tæniopteris*, a species of *Pecopteris*, the furcate-veined tripinnate frond, the *Cycadaceæ*, the *Phyllotheceæ*, disk-bearing *Equisetites*, the stems with obliquely striated bark, and some of our seeds or seed-vessels. It may be that these Indian strata constitute a sort of passage between the Lias and Trias, as has been suggested by Mr. Jones in a valuable note on *Estheria*†; and certainly the *Ceratodi* of Máledi cannot fail to call to mind the Bone-bed of Aust; but, upon the whole, I am still of opinion that the weight of testimony lies on the side of the Lower Jura, as I endeavoured to prove in a paper submitted to the Bombay branch of the Royal Asiatic Society in March 1853. And, on this view of the age of the contemporaneous fossiliferous strata of Western Bengal, Nágpur, Mángali, and Kotá, if we may assume the red clay at Máledi to be the same as the red clay in Dr. Bell's section, about 70 feet below the lowest of the ichthyolitic beds on the banks of the Pranhítá, we may understand how appropriately the *Ceratodus* teeth of the one locality are found beneath the *Lepidotus*, Insects, *Entomostraca*, *Unio* (?), and reticulated fronds of the other.

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3. *On the* Relative Positions *of certain* Plants *in the* Coal-bearing Beds *of* Australia.

By the Rev. W. B. Clarke, M.A., F.G.S.

In the "Observations on the Flora of the Oolite," by Baron de Zigno, published in the Quarterly Journal of the Society, No. 62,

* Quart. Journ. Geol. Soc., vol. vii. p. 272; vol. ix. p. 351.
† Quart. Journ. Geol. Soc., vol. xii. p. 376.

there is a paragraph* respecting the supposed non-verification of certain genera of plants in the Australian coal-fields, which were reported by me in 1847.

It is only right that I should offer a few words of comment on that paragraph.

By reference to the same number of the Quarterly Journal (p. 147), it will be seen that Mr. Selwyn has already recognized in Eastern Victoria "true Carboniferous plants;" and he further states that "in Tasmania the coal-bearing beds rest quite conformably on and pass downwards into calcareous beds, the fossils from which are, I believe, nearly all Carboniferous or Devonian forms."

Now this is precisely the case in New South Wales, in which colony the plants said to be Jurassic occur (coal-cliffs, Mulubimba, near Newcastle, mouth of Hunter River) in the same beds and blocks with heterocercal Fishes, one of which is figured by Dana † as *Urosthenes australis,* and was acknowledged by Agassiz to be a palæozoic fish.

In other portions of New South Wales, and in the new colony of Queensland, in close connexion with calcareous beds holding abundance of "Carboniferous and Devonian" zoological forms, occur shales and fine calcareous grits charged with the plants which I reported in 1847, and which Baron de Zigno does not find verified by Messrs. Morris and McCoy.

The latter gentleman examined and reported on the collections which I forwarded to Professor Sedgwick, and which are now deposited in the Woodwardian Museum at Cambridge; but he did not mention the fossils alluded to by De Zigno, because I did not, at that time, include them in my collections for the university. Nor could Professor Morris mention such in his account of the fossil flora published in Strzelecki's work, because at that time none of the older forms had been found by Count Strzelecki, and no one besides myself had made any discovery of such plants in Australia. But Mr. Selwyn's paper referred to above is sufficient to verify the facts I communicated, so far as concerns the particular genera to which Mr. Selwyn alludes. Moreover, I placed years ago, in the Australian Museum at Sydney, specimens of these disputed plants; and in the present year I saw one of them in the University Museum at Melbourn, which had been found in Gipp's Land.

Some years since I forwarded specimens to England, and one was considered at the time, by Professor McCoy, to be a *Lepidodendron* of the English coal-fields, so much did it resemble a well-known

* "This would not be the case with those of Australia, if the observations made in 1847 by the Rev. Mr. Clarke were confirmed; for he mentions in these deposits the presence of the genera *Sigillaria*, *Lepidodendron*, and *Stigmaria*, which would settle the question. But I am not aware that the facts thus cited have been since verified. On the contrary, no mention is made of these genera in the works of Messrs. Morris and McCoy, in which we are presented with a series of forms among which, together with local types analogous to those of India, there are species which recall the Jurassic flora of Scarborough." (Vol. xvi. p. 111.)

† Geolog. U. S. Soc Expl. Exp., pl. 1. fig. 1.

species. Afterwards another was noticed by the late E. Forbes*, who expressed his doubts whether that fossil was a *Lepidodendron* at all. The late Mr. Stutchbury mentions two from the coal-formation on the Storton River, in the vicinity of calcareous rocks which have their equivalents on the Hunter River, where the overlying coal-measures contain the Jurassic (?) forms. And he also figures one under the impression that it had not before been figured from Australia†.

In the course of my explorations in the northern districts of this colony, I found abundance of these *Lepidodendra*, with other allied genera, in a peculiar shale mentioned by the late Allan Cunningham as occurring on the Peel River ‡. This rock occurs also not far from Goonoogoonoo; and from it I have made a considerable collection, of which I now propose to forward specimens for comparison§; as they resemble in some respects Göppert's *Pachyphlœus* || rather than the usual forms of *Lepidodendra*, it may be well to ascertain whether they belong to that plant. Similar fossils exist in the neighbourhood of Wellington Valley, to the west of Bathurst; and lately I have found that abundance of them occur in the shale forming the surface in places, at Canoona (where a considerable gold-field exists), on the Fitzroy or Lower Mackenzie River in Queensland, nearly half a degree north of the tropic of capricorn, and a few miles east of the 150th meridian. They were considered by the persons who first saw them there as belonging to a "tesselated pavement," and excited great curiosity. In one of the grooves defining the leaf-scars, I detected a minute particle of gold, which had settled in it from the alluvium above.

M. Odernheimer also mentions similar *Lepidodendra* in his account of the Peel River district, published in our Proceedings ¶; and from my own inquiries I know they occur abundantly along the Manilla River, and in that part of the Liverpool Plain country which skirts the western limits of the Peel and Bingera Gold-fields, the latter of which has on that border coal (near Warialda), and just such grits and sandstones as cover the coal along the coast from the Hunter to the Illawarra; the usual underlying calcareous beds, abounding in Carboniferous and Devonian zoological forms, also making their appearance, as they do to the west of Newcastle.

I consider, therefore, that there has been a sufficient verification of some of the genera I reported in 1847**, since they have thus been found in various parts of a region extending from 23° to 37° S. lat., at least one thousand miles of direct distance.

In the collection which I exhibited at Paris in the year 1855, were included two specimens marked in the catalogue as "Lepidoden-

* Lectures on Gold, 2nd edit. p. 53.

† Report to New South Wales Government July, 1853; Parliamentary Blue Book, Dec. 1854, p. 18—20.

‡ Proceedings Geol. Soc., vol. ii. p. 109.

§ The specimens have not yet arrived, July 15, 1861.—Edit.

|| Fossilen Farnkräuter, pl. 43.

¶ Quart. Journ. Geol. Soc., vol. xi. p. 401.

** See also Quart. Journ. Geol. Soc., vol. iv. p. 60.

dron" and one "Sigillaria*," and mention is made of the probable age of them in the introduction to the catalogue of my collection †.

It cannot, then, be said that publicity has not been given to at least some of the genera I reported; and if in any of the others I may have erred from want of means of comparison in this country, yet there is no doubt that plants apparently older than those called "Jurassic" occur in Australia under circumstances no way distinguished from those which mark the reputed younger forms, in relation to the overlying sandstones and underlying calcareous beds containing true "Carboniferous" animal remains.

When Mr. McCoy wrote his valuable account of my fossils at Cambridge, he concluded from what he saw that there must be two periods of wide interval—the plants marking an Oolitic and the animals a Lower Carboniferous epoch, equivalent to that of Ireland, and without any confusion of type ‡. But discovering plants of the genera I reported occurring under the circumstances described above, and not comprehending how this could be without assuming the whole series in which coal occurs to be one consecutively, he expressed the desire that geologists would withhold their judgment till the whole evidence had been adduced. To assist in this inquiry into the true age of our Australian coal-beds, I therefore divided the succession of beds, as in the Paris catalogue before mentioned, and have since briefly described my divisions in a little work recently published at Sydney §. These divisions conveniently group the strata, even if, eventually, they have no direct bearing on epochal succession, though there really appears to be a sort of grouping in the fossils equivalent to that in the strata themselves.

It must, however, be observed that the distinguishing feature of the strata in Australia is their variableness; and to so great a degree is that observable, that I, for one, would scarcely venture in any part of the coal-fields to trust any stratum further than I could see it.

Notwithstanding this, however, there are four main groups of strata, generally sufficiently distinct for such divisions as I have made, and which show that it is scarcely right to class them, as has been done, in two widely distinct formations.

The evidence now collecting as to the formations in other countries seems also to show that, so far as they are concerned, but little light is thrown on the age of the Australian coal-beds; for if, as Baron de Zigno maintains ||, the Richmond plants, and, as Mr. Bunbury says ¶, the Indian plants do not prove what has been deduced from them, so it may come to pass that the evidence hitherto derived from the Australian flora may, on further examination, receive a modified form.

At present no notice has been taken as to the association of

* See British Catalogue Expos. Universelle 1855, p. 102.

† *Ibid.*, p. 100, and P. S. p. 103.

‡ Ann. Nat. Hist., vol. xx.

§ Researches in the Southern Gold-fields of New South Wales, chap. xiv.

|| Quart. Journ. Geol. Soc., No. 62, p. 112.

¶ *Ibid.* p. 115.

certain Fishes with the so-called Jurassic plants; for the fact that a palæozoic Fish was found in one of the pits at Newcastle in the same block with the Plants in question, which are called Oolitic, has not shaken faith in the latter assumption. Yet that fact must be explained away before the view in question ought to be adopted.

And if it should be found that certain genera, such as *Glossopteris* and *Sagenopteris*, are not always of so recent date as the Jurassic epochs; if it should also be found that the supposed palæozoic plants (*Lepidodendra*, &c.) ascend higher than the Lower or Upper "Carboniferous," then it may be that (which I have been inclined to believe may be the case) there is an epochal as well as stratigraphical succession in the Australian coal-bearing beds. The only way to settle the doubt unmistakeably would be to have a complete and careful measurement made of all the beds supposed to be contemporaneous in all the Australian colonies, and to collocate them after due investigation.

But that is at present an "impossible quantity;" we must be content with such evidence as we have; and as a contribution to the general data, I will make a few further remarks.

In Victoria, the geological survey obtained in the early part of this year a *Tæniopteris* from the neighbourhood of Cape Paterson, and have recently obtained other plants of supposed like age from the neighbourhood of Geelong. These fresh discoveries have been taken to demonstrate the Oolitic age of that vicinity. Now, in my examination of the Barrabool Hills, near Geelong, in 1856, I saw enough to induce me to consider that the beds of that neighbourhood (especially about Ceres) belong to the first or upper division of the New South Wales series, and to my Wianamatta beds. But the other divisions must not be forgotten. The four divisions are—1. *Wianamatta Beds*; 2. *Hawkesbury Rocks*; 3. (*Workable*) *Coal-beds*; 4. "*Lower Carboniferous Rocks*" of McCoy:—

"Jurassic" (McCoy).	1. Wianamatta Beds. Upper Carboniferous. 800 to 1000 feet thick.		Upper Carboniferous or Permian (Dana).
	2. Hawkesbury Rocks ("Sydney Sandstone" of Dana).		
	3. Coal-seams of Newcastle, &c.	Middle Carboniferous.	
"Palæozoic" (McCoy).	4. Lower Carboniferous Rocks.		

In New South Wales the Wianamatta beds contain Fishes, which are heterocercal and certainly not so near to *Pholidophorus* as to *Palæoniscus*, to which I consider some of them to belong. A species of *Phyllotheca*, as well as *Sphenopteris*, is found in the same beds with the Fishes; and a Mytiloid shell accompanies them.

The following Plants from this division I sent to Cambridge, and they were determined by Mr. McCoy:—

Gleichenites odontopteroides.	Pecopteris tenuifolia.
Odontopteris microphylla.	

[*Phyllotheca Hookeri* is marked in the memoir from Clarke's Hill; but it is a mistake probably from accident, as that species belongs to much lower beds than these.]

I have recently procured a species, with Fish, from the same division, which in some respects resembles a *Tæniopteris*, but is probably not such. It will be forwarded to England. In Tasmania, both in 1856 and in 1860, I examined carefully the section from Launceston to Hobart Town, right through the island, and traced what I believe to be an equivalent of my Wianamatta beds of New South Wales, from the neighbourhood of Spring Hill nearly to the Derwent. They appear to be in great force about Green Ponds and up to Lovely Banks, near which I found beds before unnoticed as fossiliferous, in which are plants of a different character to any hitherto found in that or this country. I will also forward them.

The second division, or Hawkesbury Rocks, are in Strzelecki's book classed as *Pliocene**; but the Fishes contained in them are nearer to *Platysomus* and *Pygopterus* than to any Tertiary genera; and over them the Wianamatta beds attain a thickness of from 800 to 1000 feet. No Plants from these rocks were sent to Cambridge, because I had not then found any. But in the beds with the Fish were *Sphenopteris*, &c., and in the massive sandstones, along the Hawkesbury itself, I have found casts of large fronds like *Odontopteris*. Neither in Victoria nor in Tasmania have I seen any beds which I can consider the direct equivalents of these, either in mass or in distinct resemblance; but patches of sandstone underlying the supposed Wianamatta beds, about the descent to Bagdad and Brighton, occur in Tasmania, which might occupy their position. As Mr. McCoy considers these two divisions with the third, or the workable coal-beds, to belong to the Oolite, it becomes important that the new fossils should be examined. But Mr. Dana considers † that these same three divisions belong to the true "Upper Carboniferous or partly Permian." I have already alluded to the Fish *Urosthenes australis*, on which in part, as well as on certain Plants, as *Nœggerathia elongata*, Mr. Dana founded his opinion.

The Plants from the third division (which cannot be separated from the second, as the Hawkesbury Rocks cover and pass into the coal-measures, containing coal-seams in their lowest masses) are, as indicated by Professor McCoy's memoir, as follows:—

Sphenophyllum (Vertebraria) australe.
Sphenopteris lobifolia, *Morris.*
—— alata, 1 *var.* exilis, *Morris.*
—— hastata.
—— Germana.
—— plumosa.
—— flexuosa.
Glossopteris Browniana, *Brongn.*
Glossopteris linearis.
Nœggerathia (Zeugophyllites) elongata, *Morris.*
Phyllotheca australis, *Brongn.*
—— ramosa.
—— Hookeri.
Otopteris ovata.
Cyclopteris angustifolia.

The other plants described by Professors Morris and Dana belong to this division ‡.

* p. 129.

† Geol. U. S. Explor. Exped., p. 495.

‡ The following are the plants enumerated by Morris:—

Sphenopteris lobifolia.
—— alata, *var.* exilis.
Glossopteris Browniana, *Brongn.*
Pecopteris australis.
Pecopteris odontopteroides.
Zeugophyllites elongatus.
Phyllotheca australis, *Brongn.*

Thus far, it may be said the evidence went up to a certain period. But no place has been found for the plants whose verification was doubted. Where do they belong in Prof. McCoy's gap between the Oolite and the "Lower Carboniferous"?

It might be said truly they are "Upper Carboniferous." But in 1859 a discovery was made at Stone Creek near Maitland, which again complicates the question. Mr. Bourne Russell made two pits at the place mentioned, and passed through four or five workable seams, the beds between which and on the top, consisting of coarse grits and conglomerates full of *Pachydomi*, *Spiriferi*, *Orthoceratites*, large *Conulariæ*, *Asteridæ*, &c., prove that these coal-seams are not in beds supposed to be Oolitic, but in McCoy's Lower Carboniferous. And to complicate still further the whole, below the coal-seams a bed of shale was reached in which are impressions of *Nœggerathia* (or *Zeugophyllites*), *Glossopteris* (or *Sagenopteris*), and other plants, such as *Cyclopteris*, that look as much like Jurassic as any that are so called.

Mr. Russell, at my request, placed at my disposal the whole series of excellent specimens, with memoranda of depth, &c. The locality is known to me, and I collected *Pachydomi*, &c., abundantly from the vicinity; so that these seams and Plants unquestionably occur in the midst of beds considered to be Lower Carboniferous.

I do not pretend to explain this anomaly, if it be one: but it is deserving of notice that the supposed *Lepidodendra*, &c., do not occur in the same beds with the *Glossopteris*, &c., described by Mr. McCoy, but they occur apparently in similar relation to the animal remains in other parts of the country. And they may, for anything known to the contrary, occupy a corresponding position in relation to the lower members of the "Lower Carboniferous" rocks as the supposed "Jurassic" plants do to the upper members of that formation. The whole affair is mysterious, and leads to an opinion that the hitherto received conclusion must be modified.

Within the last few years the search for coal has been greatly on the increase in New South Wales; and various deep shafts have been sunk between the back of the cliffs at Newcastle and the junction of the Hunter and Williams Rivers, near which at Muree (Raymond Terrace) many of the animal remains described by McCoy, Dana, and Morris were found. Some of these shafts show an uninterrupted series of coal-measures to a depth of 400 feet, without reaching the floor of the basin. Coupled with the facts already enumerated and divers others, such as the occurrence of coal and

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By Dana:—

Coniferæ.
Nœggerathia spatulata.
—— media.
—— elongata, *Morris*.
Sphenopteris lobifolia, *Morris*.
Glossopteris Browniana, *Brongn.*
—— ampla.
—— Reticulum.
—— elongata.
Glossopteris (?) cordata.
—— linearis, *McCoy*.
Phyllotheca australis, *Brongn.*
Clasteria australis.
Anarthrocanna australis.
Cystoseirites (?).
Austrella rigida.
Confervites (?) tenella.

fossilized wood in the midst of the Muree fossils,—the existence of coal in association with beds of fossils of Lower Carboniferous age on the Page River, as at Coyeo and at the back of Mount Wingen, where the coal-beds (on fire) contain plants equivalent to those of Mulubimba, and appear to be lower than the Spirifer-bearing beds on the ranges above them,—the occurrence of similar phenomena as to the presence of the fossilized wood both in the Glossopteris-beds of Mount Keera and in the Spirifer-beds of Black Head, and others elsewhere—it does clearly appear that, in the present state of our knowledge of the stratigraphical disposition in New South Wales, it is impossible, without a grave doubt, to admit that the whole of our coal-measures, if any, are of Oolitic age. A more likely solution of the difficulty would be the adoption of the conclusion that either the plants are not necessarily "Oolitic," or, if some of them are, there is a descending order of an epochal, as well as successional kind, which may fill up the gap assumed in theory, by sufficient evidence to remove the difficulty there is to all in receiving it as satisfactory.

That the Carboniferous formation in Australia, whatever becomes of the disputed beds, is of very great thickness, may be conceived from the fact determined by me when I was in Tasmania last March, that the "siliceous breccia" of Strzelecki* is a member of this formation. Mr. Gould, the accomplished director of the Geological Survey of Tasmania, will, it is to be hoped, very shortly furnish us with certain data respecting some of the points discussed above.

As much of the coal of the southern part of Tasmania is chiefly anthracite, it would be interesting to show whether it is older than the seams of Jerusalem, Richmond, Jericho, Fingal, the Mersey, &c., and if any phytological evidence exists for connecting it with the age of the *Lepidodendra*, &c., of New South Wales; whether all the coal in Tasmania is younger than the whole of the "Carboniferous" beds with animal remains; whether the coal of the Mersey is connected with the latter in the same way as the coal is at Stony Creek near Maitland, or is rather related to the coal of the Tertiary deposits near Launceston.

If it is the case that in India genera of plants stereotyped as "Jurassic" are found in varying species in other formations besides; if the identity asserted for such plants in distant countries, such as India and Yorkshire, is disproved—if the Richmond plants are now acknowledged to be older—if the reputed age of certain plants in Africa is in the same category,—it may, perhaps, be yet proved that the assumption of the "Oolitic" era for that of the Australian coal is also too general a deduction conjointly from such facts as we have and from the want of more, especially such as the want of good unmistakeable deposits in which the animal remains will leave no further room for doubt. Beyond two specimens found in the superficial Tertiary gravel at Melbourn, no one has pretended to have discovered *in situ* any shell or other animal remains of Oolitic age

* Pl. 5. fig. 2.

in all Australia *. Loose on the surface in the neighbourhood of Grafton, on the Clarence River, a portion of an Ammonite was also picked up and brought to me; but it may have been dropped by an emigrant from Europe, and is of no value in so important a question.

Different, however, is the testimony of my late friend Leichhardt, who was both a good botanist and a good geologist, and who left with me his MS. journal, in German, of a geological excursion to the northward in the year 1842. He therein mentions that he obtained a plant (named by him, doubtfully at the time, "*Equisetum obtuse striatum*?" but which was afterwards found to be a *Phyllotheca*) from one of the lowest beds in the section at Harper's Hill, so well known for its abundant "Lower Carboniferous" animal forms; and he further says that he considers that bed was equivalent to one of the beds in the cliff at Newcastle. There is no doubt that that plant was in the midst of, and far below, shells and other fossils respecting which there is no dispute. It is, in short, a fact well agreeing with the evidence from Stony Creek.

In venturing on this extended discussion of a difficulty, my chief object has been to show that the age of the Australian coal-beds is not sufficiently determined at present to justify their being used as a test of "Jurassic" age of coal-beds in other countries.

At the same time I may add how much I have been gratified in obtaining Baron de Zigno's work, and that, notwithstanding all I have written, I am open to the conviction of evidence.

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4. Prof. HUXLEY, Sec.G.S., made the following observations on some Reptilian Remains from North-western Bengal:—Some bones, found by Mr. Blanford in the uppermost portion of the "Lower Damūda" group of strata in the Ranigunj coal-field, and forwarded to Prof. Huxley by Dr. Oldham, have proved to belong to Labyrinthodont Amphibia and Dicynodont Reptiles,—hereby affording new and interesting links with the fossil fauna of the Karoo Beds of South Africa, and largely increasing the probability that the rocks in which they were found are of Triassic age.

Notes on some further Discoveries of FLINT IMPLEMENTS *in Beds of* POST-PLIOCENE GRAVEL *and* CLAY; *with a few Suggestions for Search elsewhere.* By JOSEPH PRESTWICH, Esq., F.R.S., Treas.G.S.

[This paper, read on May 8th, is, by order of the Council, printed in the August No. of the Journal, that it may be as useful as possible to geologists during their autumn excursions.]

SINCE my communication to the Royal Society † on the discovery of Flint Implements in post-pliocene beds at Abbeville, Amiens, and Hoxne, similar implements have been found in a few new lo-

* Fossils of Upper Mesozoic age have been brought to England from Western Australia by Mr. F. T. Gregory, and noticed in his paper read before the Geological Society on May 22, 1861.—EDIT.

† Phil. Trans. for 1860, p. 277.

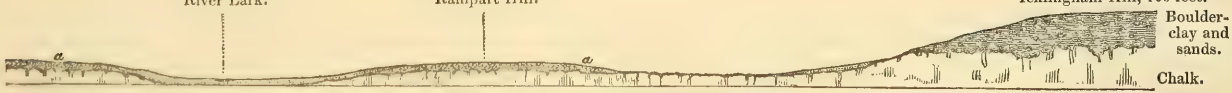
calities in this country as well as abroad. It is not my object at present to enter into a full account of these additional discoveries, or to touch upon the many and tempting theoretical considerations which suggest themselves, but which yet require further and more varied data. It is for these reasons that I limit myself to a brief stratigraphical description of these localities, for the purpose of directing attention to them before our Session closes, and also to suggest a few other localities where search should be made, in the hope that during the ensuing summer other members of the Society, who may have the opportunity of visiting some of these places, may join in the search and discover fresh facts to throw additional light upon this interesting inquiry.

Suffolk.—In the course of the summer of 1860 Mr. Warren, an antiquary residing at Ixworth, near Bury St. Edmonds, searching for Roman antiquities at Icklingham, between that town and Mildenhall, received from one of the workmen a peculiarly worked flint implement. The man told him he found it at a depth of 4 feet, in digging the gravel at Rampart Hill. Shortly afterwards Mr. Warren in looking over a heap of gravel by the road-side in that neighbourhood, found another specimen 5 inches long and of similar form. He communicated the discovery to Mr. Evans, and this gentleman and myself took an early opportunity of visiting the place. In descending the valley of the River Lark, below Bury St. Edmonds, we traced, at a level a little above the river, a nearly continuous bank of gravel. At Flempton I discovered in this gravel a small fragment of some mammalian bone*, but neither there nor elsewhere did we meet with any flint implements. The gravel is composed chiefly of sub-angular flints in an ochreous sandy matrix. Mixed with it are a considerable number of siliceous pebbles from the conglomerate beds of the New Red Sandstone, with pebbles of the older rocks, and fragments derived from the boulder-clay, than which, both from its position and these mineral contents, I believe it to be newer. It is spread out in rough irregular beds interstratified with seams of sand. We could find no shells. The following section (fig. 1) shows the relation of this gravel, *a*, to the valley and to the boulder-clay.

Although the two specimens in Mr. Warren's collection want more conclusive evidence as to their original position, yet neither Mr. Evans nor I feel much doubt of their derivation from true drift-gravels; for in *shape, staining*, and *condition* they agree precisely with the flint implements of the valley of the Somme. The Icklingham gravels should now be the object of a careful and long-continued search. This is the second locality where flint implements have been found in Suffolk; Hoxne being situated in the north-east part of the county adjacent to Norfolk and in the valley of the Waveney, which runs into the German Ocean. Icklingham, on the contrary, is within a short distance of Cambridgeshire, and in the valley of the Lark, flowing into the Ouse, which empties itself into the Wash at Lynn.

* Teeth of the *Elephas primigenius* are found in the gravel elsewhere in the neighbourhood of Bury St. Edmonds.

Fig. 1.—*Section across the Valley of the Lark, nine miles below Bury St. Edmonds.*

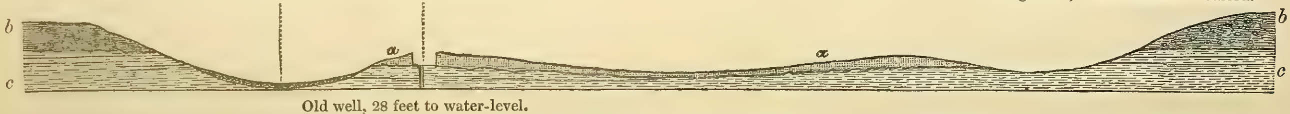


a. Sub-angular gravel with flint-implements.

Fig. 2.—*Coast-section from Reculvers to Whitstable Bay.*

a. Freshwater deposit. *b.* Coast-guard station. *c.* London clay. *a.* Freshwater deposit.

Fig. 3.—*Section across the Valley of the Ouse near Bedford.*



a. Sub-angular gravel with mammalian remains, freshwater shells, and flint-implements. *b.* Boulder-clay. *c.* Oolitic strata.

Kent.—In August last year Mr. T. Leech, while searching for fossils in the cliffs between Herne Bay and the Reculvers, accidentally found in the shingle at the foot of the cliff a well-formed flint implement. This induced him to make further search, and in the course of the few weeks he spent there he found altogether six specimens. They are all of the spear-head pattern, so common at Amiens. One specimen, however, is peculiar, and so far unique; it is a pointed implement formed out of large, smooth, egg-shaped tertiary *flint-pebble.* One end of the pebble is brought to a sharp point, and the other retains its smooth, rounded surface. In February last Mr. Evans and I, accompanied by Mr. Leech, visited the place, and after a search of some hours, Mr. Evans found two, and I found one well-made and undoubted specimen. They were lying on the sand and shingle at a distance of from 20 to 30 feet from the foot of the cliff, and distant three-quarters of a mile west from the Reculvers, and a little to the eastward of Old Haven coastguard-station*. We searched the cliff for them *in situ*, but without success. It is to be hoped that the upper part of the cliff—the part to be searched—may prove more accessible during the summer months. I satisfied myself, however, so far as to determine that at that spot there is at the top of the cliff, which consists in its lower part of the Thanet sands and Woolwich series†, a local pebbly clay deposit of small extent and about 8 feet thick, and which, I have reason to believe, is of fresh-water origin, as it closely resembles the fossiliferous deposit next mentioned. It is to this bed that I would refer the flint implements. Its height above the sea-level is about 50 feet. The annexed section fig. 2 shows the relation of this bed, *a*, to the sea-level, and to the presumed older gravels, *b*, which cap the higher ground.

A few years since I found, in a section at Swalecliff near Whitstable, a freshwater deposit (*a* in the western part of fig. 2), overlying the London clay, and abounding in land- and marsh-shells, with which were associated a few mammalian bones. I again visited the spot on my return from Abbeville in 1859, in the hope of finding flint implements. My search, however, was not successful. We now again returned to this spot to make a further investigation. On this occasion we had no sooner reached the small bay east of the cliff, than Mr. Evans was fortunate enough to find, lying on the shore, an oval-shaped flint implement, identical in form with those so common at Abbeville. The specimen was further interesting from its deep discoloration. It possesses that bright light-brown colour which characterizes the specimens from the gravel of Moulin Quignon. We searched the cliff for specimens *in situ*, but did not succeed in finding any. We noticed, however, that the fossiliferous clay was underlain by a bed of gravel, the flints in which had the same peculiar brown colour as

* An old wooden spout projecting from the upper part of the cliff may at present serve as a guide to the spot.

† For the general section of this part of the coast see my paper in the Journal, vol. viii. pt. xv. p. 264.

the flint implement. On a subsequent visit, Mr. Evans found a small fragment of the tooth of elephant in this gravel high up in the cliff. This freshwater bed forms one of a series which, commencing at Chislet* near Grove Ferry, where the deposit contains the *Cyrena fluminalis* with other fresh-water and also some few marine fossils, seems to fringe, at intervals, this range of hills. This particular deposit at Swalecliff, although consisting of tenacious clay with an interstratified bed of sand and of gravel, is more analogous to the loess in its organic remains than to the Wear Farm deposit; for hitherto, although the *Pupa marginata* and *Succinea oblonga* are extremely abundant, and a small *Helix* is not rare, yet I have not been able to obtain a single truly aquatic shell. The relation of these beds to the boulder-clay is not here shown.

Bedfordshire.—Another important and better-observed discovery has just been made near Bedford, by Mr. James Wyatt, F.G.S. A few years since, a remarkable number of the bones of the *Elephant, Rhinoceros, Hippopotamus, Ox, Horse*, and *Deer* were discovered in cutting through a bank of gravel about one mile north of Bedford on the Great Northern line of railway†. Mr. Evans and I shortly afterwards, accompanied by Mr. Wyatt, visited this and other sections of gravel near Bedford. The following year Mr. Evans discovered in the large gravel-pit at Biddenham, two miles W.N.W. from Bedford, both land- and freshwater-shells at a depth of 8 feet from the surface. These circumstances, combined with the experience acquired by a visit to Amiens in the autumn of 1860, induced Mr. Wyatt to turn his particular attention to this pit, which has since been to him the object of almost a daily pilgrimage. After a search, continued for many months, he has at last been rewarded by finding two well-formed flint implements, one of the spear-head shape and the other oval,—counterparts, in fact, of the two chief French types. The men had been digging deeper than usual, and it was in a heap of gravel just thrown out from a depth of about 13 feet that Mr. Wyatt found on the same day both specimens. A letter‡ from that gentleman gives the details of his interesting discovery. I have since visited the pit in company with Sir Charles Lyell, Mr. Evans, and Mr. Wyatt. It is situated on slightly rising ground, about 30 to 35 feet above the level of the adjacent River Ouse (fig. 3). It happens that there is an old well in this pit, the sill of which is about 7 feet below the former level of the ground. I ascertained the level of the water to be 21 feet 9 inches below the sill. This therefore gives us 29 feet from the top of the ground; and if we add, say one foot, for the fall of the water-line to the river, we have 30 feet as the height here of the top of the gravel *a* above the level of the river. The following is

* See another paper by the author, in the Journal of the Society, vol. xi. p. 111.

† A very large quantity of the bones were collected by Mr. Reade; but unfortunately no systematic search was made, and, with this exception, no collection formed.

‡ It is not now necessary to publish this letter, as it is embodied in a communication (to which I beg to refer the reader) by Mr. Wyatt, to the 'Geologist' of June, in which the sections used in illustration of this paper and other particulars are reproduced.

the section at that part of the pit where the implements were found:—

	ft.	in.
a. Earth and gravelly soil	1	0
b. Coarse light-coloured gravel, upper part irregularly stained brown with apparently infiltrated clay	5	7
c. White and yellow sand, with *Limneus*	1	8
d. Whitish fine gravel	1	0
e. Seam of ochreous sand and grey clay, with *Helix* and *Limneus*	0	3
f. Seam of light-grey sand and gravel	3	0
g. Ochreous gravel with an irregular seam of grey sandy clay, containing *Cyclas* and *Limneus*	1	0
The two implements are supposed to have come from the bed *g*.	13	6

The seams are very variable. The gravel is subangular, and is composed of fragments of flint, local Oolitic débris, pebbles of quartz and of siliceous sandstones of the New Red Sandstone conglomerates, with fragments of various old rocks. In the lower bed are a considerable number of small blocks of sandstone, oolites, and large flints. The shells are dispersed throughout from a depth of 5 feet to the base. They are mostly in fragments, but occasionally perfect. I have, with the assistance of Mr. Pickering, determined the following species:—

Cyclas corneus.	Bithinia tentaculata.
Pisidium amnicum.	Limneus auricularis.
—— pulchellum.	—— pereger.
Helix hispida.	Planorbis carinatus.
—— pulchella.	Valvata piscinalis.

A considerable number of the teeth and bones of the *Elephas primigenius*, *Rhinoceros tichorhinus*, and of the Horse, Ox, and Deer have been found in this pit, chiefly at or near the bottom of the gravel. Now it is evident that a certain portion of the materials of the gravel are local, but still there is a large foreign element independently of the flints. As the valley drains only an oolitic district, which could not have furnished any such materials, it is evident they must have been derived from the boulder clay, which caps the hills of the district and contains all the required elements. The hills north of Bedford consist of boulder-clay, *b*, as do also those west of Biddenham; they both rise to a height of about 100 feet above the river, and are separated by a valley two miles broad. In this valley the gravel forms a wide, nearly level tract, 60 to 80 feet lower than the hills, but still 20 to 40 feet above the level of the present river. We have here therefore, as at Hoxne, another good case of the flint-implement-bearing beds being newer than the boulder-clay; whilst in general physical characters and in the nature and variety of the organic remains we are strongly reminded of the gravel beds of St. Acheul, near Amiens.

Surrey.—Twenty-five years ago, Mr. Whitburn, of Guildford, was examining the gravel-pits at Peasemarsh, between that town and Godalming, for fossil bones (of which a considerable number, including those of the Elephant, had been found here), when his attention was attracted by a peculiarly shaped flint lying in a bed of sand, interstratified with the gravel, at a depth of about 4 feet from the surface. He took it away and preserved it in his collection as an object of antiquarian rather than of geological interest. Hearing, however, of the late discoveries at Amiens and Hoxne, he sent the specimen, with an account of his finding it, to Mr. Evans. It is an undoubted flint implement, rude and of a peculiar wedge-shaped form. I have one specimen from St. Acheul with which it closely agrees. This of course can be considered but as a possible instance.

Hertfordshire.—It is only ten days since Mr. Evans, while walking with some antiquarian friends from Nash Mills to Abbots Langley, was struck with the great number of quartz, siliceous sandstone, slate, and other old rock-pebbles and fragments scattered over a field near the latter place, and was still more surprised at finding, among this surface-drift, a weathered flint implement with the top broken off, but otherwise identical in form with the spear-head-shaped specimens from Amiens and Herne Bay. Although found on the surface, Mr. Evans, who is most competent authority on this point, does not consider it to belong to the Stone-period. On the contrary, he would refer it to the Pleistocene age. I have been with him to the spot where it was found. The chalk hills are here about 200 feet above the level of the Boxmoor valley, and are in places bare, and in other places thinly covered with gravelly drift. Between this peculiar drift and the flint implement I myself saw no connexion, and I can merely mention the fact without venturing to speculate upon it.

We have thus, at all events, three additional counties in which Post-pliocene flint implements have been found; and I would now direct attention to a few other localities where there are beds of fresh-water gravel and sand, or of freshwater and other associated gravels, in which I think it highly probable that flint implements may occur.

Places for further Search.—I would more especially direct attention to the gravel- and clay-pits at Copford, Lexden near Colchester, and Sudbury; the brick-pits at Erith, Grays, Ilford, Maidstone, and Salisbury; the low-level gravel-beds at or near Alton, Axminster, Bath, Blandford, Brentford, Cambridge, Chartham, Chesterford, Chichester, Chippenham, Croydon, Defford, Dover, Farnham, Faversham, Folkstone, Gloucester, Godalming, Hackney, Hertford, Hurley, Kingsland, Oxford, Peasemarsh, Reading, Selsea, Stafford, Stamford, Stroud, Taplow, Wandsworth, Westbury, Worcester, and Orton near Peterborough, as some of the places in the south of England where, I think, flint implements may also, by diligent search, possibly be found. I say "diligent," because even in places where they are most abundant, as at St. Acheul, the search must be long before the observer is rewarded by finding a single specimen; whilst in other places the search often seems for a time almost hopeless. Judging from precedents, our motto should be *Nil desperandum.*

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From January 1st to March 31st, 1861.

I. TRANSACTIONS AND JOURNALS.

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Albany. Twelfth Annual Report of the Regents of the University of the State of New York. 1859.

American Journal of Science and Arts. Second Series. Vol. xxxi. No. 91. January 1861. *From Prof. Silliman, For.M.G.S.*

W. E. Logan.—Track of an Animal in the Potsdam Formation, 17 (figures).
W. Gibbs.—Platinum metals, 63.
J. L. Smith.—Guernsey County (Ohio) Meteorites, 87.
Bunsen.—New Alkaline metal, and Spectrum-analysis, 105.
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Tylor, E. B. Anahuac: or Mexico and the Mexicans, ancient and modern. 1861.

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

April 10, 1861.

James Hector, M.D. Edinb., 13 Gate Street, Lincoln's Inn Fields, was elected a Fellow.

The following communications were read:—

1. *On* Elevations *and* Depressions *of the* Earth *in* North America. By Abraham Gesner, M.D., F.G.S.

(Abridged.)

United States.—Commencing at New Jersey, in the United States, the writer has examined nearly all the most interesting parts of the coasts, as far northward as the northern part of Labrador. The whole south-eastern side of New Jersey, where it borders upon the Atlantic, to the extent of 100 miles in length and about 20 miles in breadth, is composed of alternate strata of sand, greensand, marl, and clay, some of the beds very highly fossiliferous. The land is comparatively low, and slopes gradually from the high lands in the rear towards the sea. A similar tract of country occurs in the bordering State of Maryland, and, still further southward, in North Carolina.

The oldest inhabitants of New Jersey, whose lives have been extended to upwards of eighty years, maintain that within a period of sixty years the sea has risen upwards of four feet, or, what is equivalent thereto, the coast has fallen to that depth. Marshes that were formerly mowed for their grass are now submerged; the sea has encroached upon the land, even over the sites of ancient habitations. There are tracts where trees are seen growing upon fallen forests, which have been buried in sand and peat. Timber of excellent description is dug out of the present marshes. The amount of depression along this coast is variously estimated as being from 5 to 12 feet.

From these, and other facts which might be quoted, it appears that there are marine Cretaceous deposits, and over them Pleistocene deposits with freshwater shells and Mastodon bones, and apparently an old forest buried in sand, with the remains of another growing over it—these two being under the sea in some places and therefore proving submergence of a land-surface,—and that this submergence is still going on, according to the testimony of the inhabitants and the submergence of habitations.

In the harbour of Nantucket, there is a submarine forest. In dredging the estuary, Lieutenant Prescott found trunks and roots of the cedar, oak, maple, and beech, some of them standing upright and still attached to the soil on which they flourished. Excepting the cedar, all the woods are still sound. The trees are partially buried in sand, and are eight feet below the level of the lowest tide.

A similar submarine forest exists at Holme's Hole, on Martha's Vineyard. On the west side of the harbour, stumps of trees are found standing upon a level surface beneath the water; another woody tract occurs near the south-west extremity of the Vineyard, and on the north side of Cape Cod, opposite Yarmouth: the latter extends more than three miles into Barnstable Bay. At Portland a similar sinking of the land has been clearly made out. In none of these instances is there any accounting for the facts, but by actual subsidence. No indications of elevation were observed in this quarter.

New Brunswick.—Proceeding in a northerly direction, we arrive at the River Schoodiac, or St. Croix, the dividing-line between the United States and the British Province of New Brunswick. Instead of submergence, an elevation of the land is here clear and distinct. It extends in a northerly direction upwards of twenty miles, and probably to a still greater distance along the coast in the direction of the Bay of Fundy. The greatest elevation is near the centre of this area, which has been but little raised at its edges. The solid rocks beneath the modern marl-beds are chiefly red sandstone, syenite, and granite, with intrusions of trap-rocks.

At St. Andrew's, St. Stephen's, Lubec, Eastport, and numerous sites in the adjacent districts, there are extensive deposits of sand, marl, and marly clay, containing relics of shells and sea-weeds which still inhabit the present shores; and the former are so numerous, that they have contributed sufficient lime to some of the strata to render them valuable for fertilizing-purposes. At first these marl-beds were supposed to be Tertiary deposits; but late observations have determined their more recent origin. The greatest elevation observed was near the town of St. Andrew's, where the marl with recent shells is found 28 feet above the level of the highest tide.

Among the numerous islands of Passamaquoddy Bay the writer observed many of the indications of elevation; nor is it difficult to discover along the borders of the creeks and rivers the sites from which the sea has been slowly and gradually withdrawn. Strata of marl and clay with shells like those before mentioned appear at Beaver Harbour, where the elevation has been less considerable.

Grand Manan is a beautiful island, situated off the mouth of the St. Croix River, and 12 miles from the American line. It is 25 miles long and 5 miles in breadth. The north-west side is a somewhat lofty ridge of trap-rock, uninhabited and presenting to the sea perpendicular and overhanging cliffs. The opposite side of the island is inhabited; and the industry is agriculture and fishing; and a number of small islands and harbours afford shelter for vessels.

The most remarkable circumstance connected with this isolated part of New Brunswick is the fact, that the entire south side of the main and its islets have within a recent period been submerged to the depth of 18 feet and upwards. There still remains a tradition that there once existed between the main, the three Duck Islands, and Nantucket Island a kind of marsh of several thousands of acres. This marsh has slowly disappeared beneath the sea; and its surface is only partially uncovered by the water at the lowest spring-tides. The roots, stumps, and trunks of a great number of trees (the pine, hemlock, and cedar) still remain firmly attached to the sunken earth, and at the very sites where they flourished. The once living forest with its branches and leaves is now deeply covered by each succeeding tide. The anchors of small craft are often held fast among the wood of the bottom of the harbour. It was by this subsidence that several islands became isolated; for the marshes that formerly attached them one to the other have been denuded and washed away by the waves. The subsidence extended to the distance of several miles westward; but it is best measured near the small islands before mentioned. Viewed altogether, it would seem that Grand Manan has slowly moved upon its axis, depressing one side and elevating the other.

At the mouth of the River St. John and at the city of the same name, in the Province of New Brunswick, the evidences of elevation are distinct over an area of twenty square miles. Between the city and Portland, there is a narrow and deep valley now occupied by a church, manufactories, and dwelling-houses. In this valley, and above strata of clay, there are marl-beds containing marine shells and decomposed sea-weeds identical with those still inhabiting the shores of the harbour. These beds are about 18 feet above the level of the sea, which at some former period surrounded the site of the city.

At Manawagonis, Mispec, Emerson's Creek, and many other places in this quarter, there are beds of sand, clay, marl, and marly clay exposed to the sea, forming low and almost level tracts along its borders. Similar deposits also occur in the banks of the St. John and Kenebecacis Rivers, above the reach of the highest tides. They not only appear where the currents have exposed the beds, but also remote from those streams. The shells are chiefly imbedded in the sand and marl, which also contain the relics of recent marine vegetation. In these deposits upwards of twenty genera of recent *Testacea* and six genera of *Crustacea* have been obtained. Some of the shells, such as the *Mya mercenaria, Pecten, Arca,* &c., are well preserved. The shells of the *Solen ensis* and *Mytili* are too brittle to be removed. The claws of crabs and the bones of fishes, although changed, are not destroyed. The shells of the uppermost beds are more decayed than those of the lower deposits, and appear as though the elevation had been slow and gradual, and not sudden like those frequently indicated in districts moved by earthquakes. The strata containing these remains are now from 10 to 40 feet above the level of the tides, which rise 30 feet along this part of the coast at spring-tides.

The rivers emptying into the Bay of Fundy along this line of coast are broken by falls at their mouths; but the streams which do not pass through this raised district empty themselves into the bay smoothly and without interruption. It is therefore not unreasonable to believe that the breaking-up of the river-beds was coeval with the elevation of the shelly deposits now removed far above the reach of the waves.

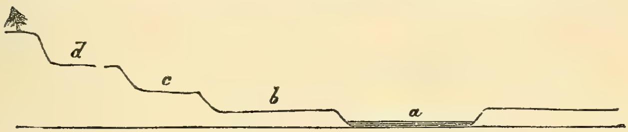
The next site to be noticed is remarkable for its submergence; it is called the Great Tantamar Mash, situated 120 miles eastward of the St. John, in the County of Westmoreland, and at the head-water of Chignecto Bay. This marsh is 13 miles long, and about 4 miles broad. Large tracts have been rescued from the sea by embankments, or "dikes," thrown up on the borders of the river and its creeks. At the eastern extremity of the Tantamar, there is a sunken tract, composed of peat-bog, floating bogs, with swamps and small lakes, not less than 8 miles long and 3 miles in width. It is the breeding-place of great numbers of wild ducks and snipes. Large trees of different kinds, collections of shells, bones of fishes, &c. appear at different depths in the alluvium. But besides these, on the northern border of the alluvial deposit, patches of forest-trees, some of which have been felled by the woodman's axe, are now overflowed by the tides. Relics of the early French settlers, Indian harpoons, and pieces of their bark canoes, and other traces of the aborigines have been dug up at depths of 5 and 10 feet beneath the surface, on the opening of canals and ditches remote from the river.

The same depressing influence has been at work at Shediac and Bay Verte. At the latter place the gravestones of persons killed by the Indians in 1755 are now reached by the tide at high water, which washes the base of old Fort Moncton, and rises above its causeway.

In the County of Northumberland, where it borders upon the Bay de Chaleurs, there has been a depression, evidently slow in its progress and continued. In the vicinity of Bay des Vents and Lower Bay des Vents, extensive peat-bogs are seen at low water reaching outwards beneath the sea: the peat is of super-marine growth, and its highest parts are scarcely above the tide-level. The shores are low and level; and evidences of land-slides are absent. At Bathurst, on the contrary, and on the opposite shore of Lower Canada, there has been an elevation of several feet, and which apparently is still progressing. A number of minor elevations and depressions were observed during the writer's geological survey of the Province, before leaving which the terraces along the Upper St. John River may be adverted to, as being connected with this subject.

On the banks of this river we frequently observe, in ascending from its borders, several parallel steps which rise abruptly from one level to another in succession. These steps are composed of diluvial matter, in which there are occasionally contained decayed timber and fragments of freshwater shells. These are well displayed near the ferry four miles below Woodstock.

Section of the Terraces near Woodstock, New Brunswick.



a. The river.
b. First terrace, 22 feet above the level of the river.
c. Second terrace, 28 feet above the level of the river.
d. Third terrace, 40 feet above the level of the river.

These several terraces mark distinctly the former banks of the river, which has been withdrawn from its ancient limits to a narrow channel with an increased velocity of current. Near the mouth of Maduxnakeag, a tributary of the St. John, the ancient bed of the stream is now dry and under cultivation. Whether these terraces have been produced by an uplifting or depressing force, it is difficult to ascertain. It is probable, however, that the site of the river was once a lake, which has been drained by the yielding of the earth further down the stream, where there are now violent rapids and marks of recent terrestrial disturbance. Terraced valleys are common on many of the rivers of North America.

Nova Scotia.—At many places in Nova Scotia, changes of level on the surface of the earth appear very distinct, although they are less manifest than they are in the sister Province. It is generally maintained by aged persons, that the tides flowing into the Bay of Fundy and Minas Basin and its numerous rivers and creeks are rising. The records of ancient landmarks, the encroachment of the water upon the dry earth, the discovery of ancient bridges and relics of the native Indians beneath the present tide-level, corroborate that opinion. At numerous places in the marshes of the Shubenacadia, Avon, and King's County Rivers, the alluvia of the sea are perfectly stratified. Some of these strata and those called "blue marsh" are composed in part of plants still undergoing decomposition and expelling carburetted hydrogen. These strata are sometimes 12 feet beneath the surface, and interlaid with beds of alluvium, which, when their layers are exposed, display with beautiful distinctness the tracks of the numerous wading birds that frequent the shores. It is almost unnecessary to add that sea-alluvia never accumulate above the highest tide-mark.

On the southern side of this Province, where it meets the Atlantic, the old fishermen universally report the effects of uplifting at certain places where they have been wont to anchor their nets and boats in pursuing their avocation. Off the harbour of Halifax, and Sambro Lighthouse, a submarine elevation appears to be advancing. A few years ago a steamer was wrecked in breakers six miles south of the lighthouse, after a gale of wind: breakers at that place were unknown before. Recent soundings also show a shallowing of the water.

Cape Breton.—In the Island of Cape Breton, situated at the entrance of the Gulf of St. Lawrence (and which the writer had an opportunity to explore under the patronage of the late noble Earl of Dundonald), several upheavings and depressions of the land were observed, not dissimilar to those already mentioned. Among the latter is that of the ancient city of Louisburg, which forms an interesting feature in Colonial history. This place was once the stronghold of France in America, and has one of the finest harbours in the world. It was well fortified; and a population of 20,000 souls was contained within its walls. It was taken from the French by 4000 provincial troops, under Colonel Pepperall, in 1745. Afterwards Great Britain restored it to France. In 1758 it was again captured by General Amherst. The place was defended by 3000 men, six ships of the line, and five frigates: in this action the brave General Wolfe won an early distinction. The inhabitants of the city were dispersed; and the British Government expended £40,000 in blowing up the fortifications. The city is now occupied by six families of poor fishermen; two stories of the hospital remain, as do the foundations of the Governor's house and other public buildings, with much of the massive masonry of the bomb-proofs and bastions. Among the ruins are seen fragments of exploded shells and other missiles, mingling with the crumbling bones of the killed. Had Louisburg continued to exist up to the present time, its abandonment would not have been the less certain; for the sea now flows within its walls and overflows sites that were formerly inhabited. Its submersion is plain and distinct. The rock upon which General Wolfe landed has nearly disappeared. The waves break against the south wall, which they have undermined and thrown down. The higher parts of the fortress afford shelter for sheep; but each succeeding tide flows freely into the northern side of the deserted city. The lands westward also bear testimony to an extensive submergence.

Prince Edward's Island.—The fertile Prince Edward's Island is situated in the Gulf of St. Lawrence, fifty miles eastward of the

Province of Nova Scotia. It is composed of red sandstone; no workable strata of coal have been found within its limits. Of several sinkings of the earth noted by the writer during his geological survey of the island, one of them merits attention for being more recent than any other that met his observation. It is situated between Lennox Island and Cascumpec, a deep and well-sheltered harbour. The sea has here thrown up mounds of sand from the shallow water, which are separated from the mainland by lagoons. The lagoon between Richmond Bay and Cascumpec is upwards of thirty miles in length. Cascumpec lagoon is a beautiful sheet of water, eighteen miles long and a furlong in breadth, abounding in shellfish and wild fowl; its mainland side is a dense wilderness, and this part of the coast was explored in canoes paddled by Indians.

The harbour of Cascumpec is formed by an extensive peat-bog on one side, and a long mound of sea-sand on the other; it has sufficient water to float the largest ships. The peat forms a perpendicular wall, which was measured at low water, and found to be 19 feet beneath the sea. It is also perpendicular above the water and forms the shore to the distance of two miles and a half. This peat-bog is composed of the common sphagneous plants interlaid with the pine, hemlock, and other forest-trees and low bushes, some of which are still in upright positions. There are no higher lands in the rear from which this bog could have made a slide, nor any remaining site from which it could have departed.

In the lagoon, the sea flowed, at the time of the writer's visit, into groves of maple, beech, birch, &c., which are constantly falling down from the sea-water overflowing their roots. The marshes, where they meet the water, are filled with fallen timber; and all taken together presents a desolate picture of the changes that are still in progress. This part of the island is very low and level; and, from the gradual submergence of the land, the drainage of the country is obstructed, and lands now capable of being cleared and cultivated, will in the course of years be overflowed by the sea, unless the submersion should be arrested.

At numerous places on the shores of the Gulf of St. Lawrence and on the coast of Labrador, deposits of sand and clay containing recent shells and relics of marine plants are found at heights varying from 5 to 80 feet above the level of the sea. These elevated tracts are seen, at considerable distances from the present shores, with notches worn out of the rocks by waves and currents of water; there are also limestones perforated by the *Mytilus lithophagus*, from which the sea has long since been withdrawn. At some localities there are also evidences of depression, similar to those already described.

Labrador, &c.—The Atlantic coast of Labrador and the Island of Newfoundland present the same phenomena, although they are less perfectly delineated by reason of the ice; for ice-floes break down the shore, and icebergs deposit mounds of sand, gravel, and boulders along the sea-bord, the winter and summer aspects of which are altogether dissimilar.

Conclusion.—From what has been stated, it must not be understood that these silent *undulatory* movements of the land are confined to the coasts and estuaries: they are manifest on the borders of the rivers and the great lakes of Canada, and also on the tributaries of the Mississippi. Slight shocks of earthquakes are common in Canada and the United States; but it does not appear, in the history of those countries, that any material change in the relative levels of certain tracts has been effected thereby. Admitting, however, that earthquakes have been the cause of sudden sinkings and elevations of the land, and which would produce anomalous results, there is a slow and constant undulatory movement of the earth's surface, which no doubt acts as much on the ocean's bed as upon the dry land.

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2. *On the* Geology *of the* Country *between* Lake Superior *and the* Pacific Ocean (*between the 48th and 54th parallels of latitude*), *visited by the* Government Exploring Expedition *under the command of* Captain J. Palliser (1857–60). By James Hector, M.D.

(Communicated by Sir R. I. Murchison, V.P.G.S.)

[Plate XIII.]

Contents.

Introduction.
General Physical Features.
Superficial deposits.
- Terraces of the Lake Superior Basin.
- Superficial deposits of the Central Plateau.
- Terrace-deposits of the Mountains.
- Terraces in California.
- Age of the Terrace-deposits.
- Drift of the Pacific Coast.

Tertiaries.
Cretaceous System.
- Group F.
- Group E.
- Group D.
- Group C.
- Group B.
- Relation of the Cretaceous Series on the West.
- Cretaceous Strata of Vancouver Island and the Gulf of Georgia.
  - Details of the Strata at Nanaimo.

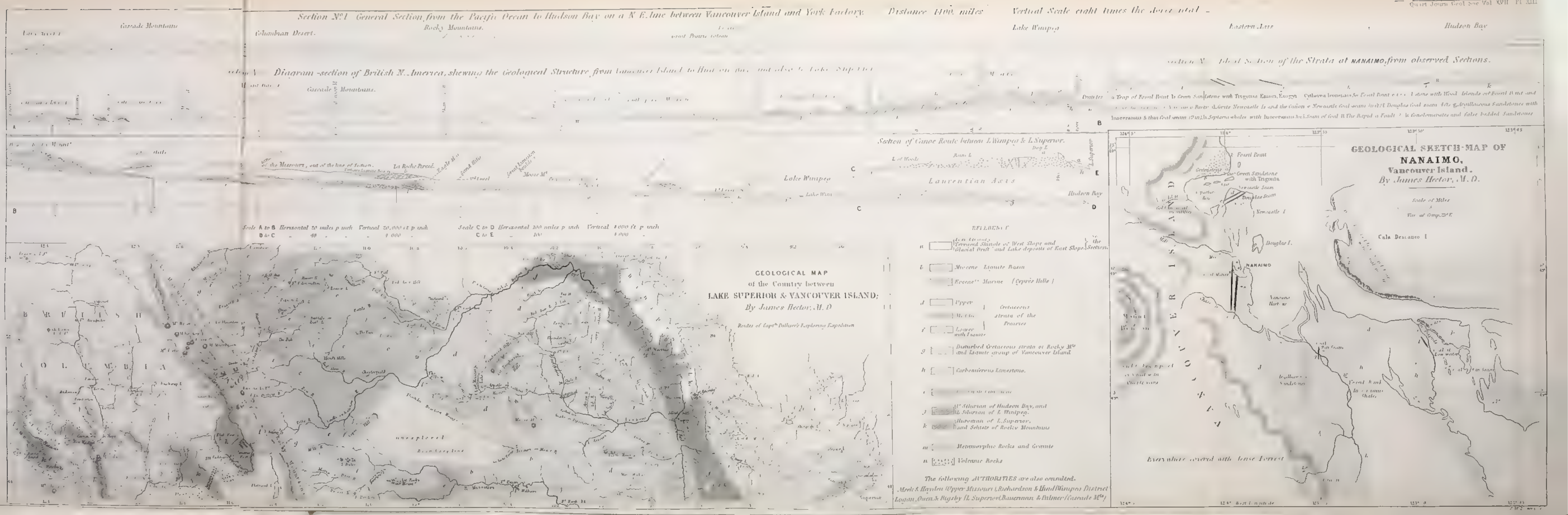
Palæozoic Rocks of the Eastern Axis.
- Silurian rocks.

Structure of the Rocky Mountains.
- Physical Character.
- Geological Structure.

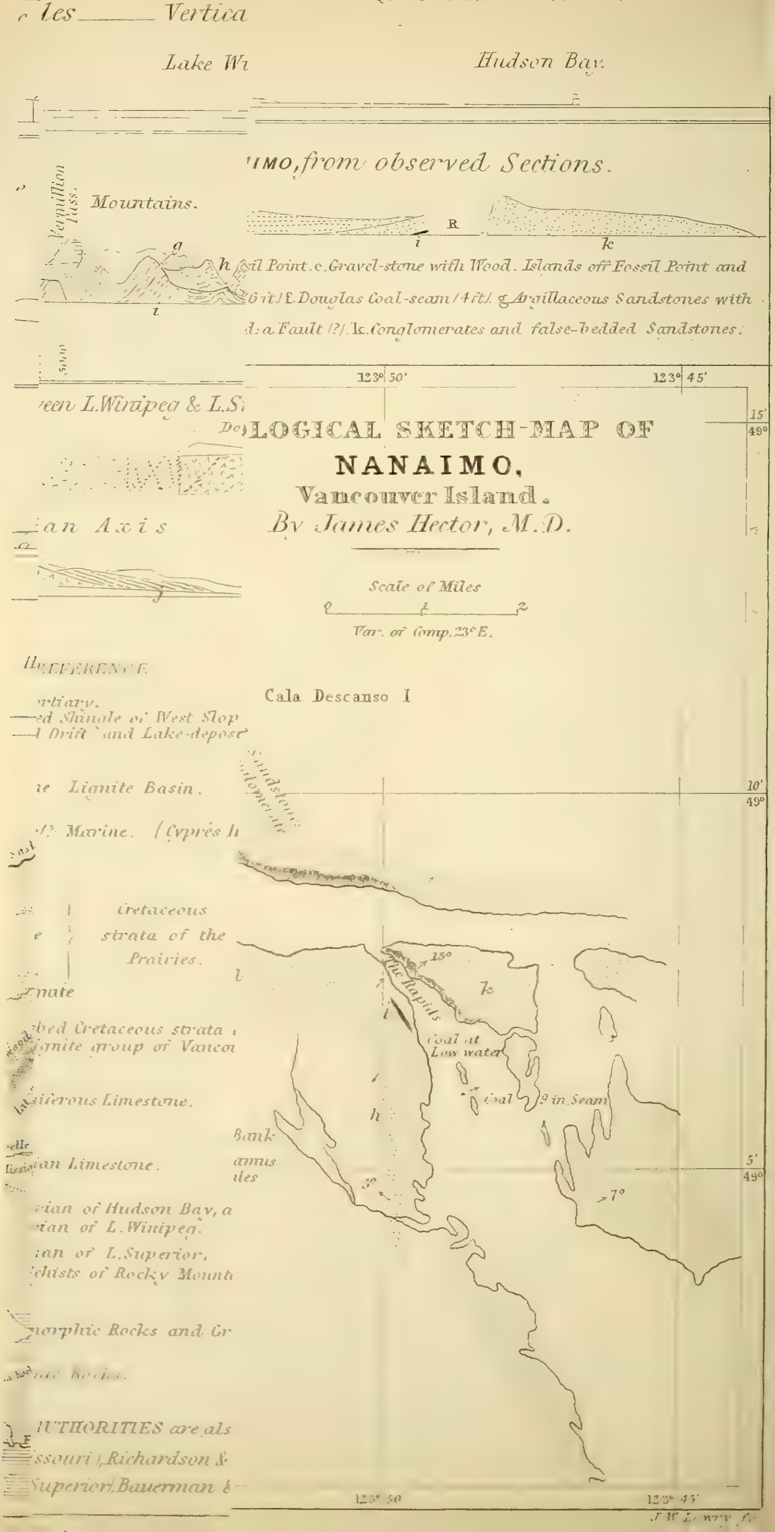
The Cascade Range.

Introduction.—In the spring of 1857 Her Majesty's Government, at the suggestion of the Royal Geographical Society, constituted an expedition to explore the British Territories in North America lying in the neighbourhood of the boundary-line of the United States, and stretching westward from Lake Superior. Public attention was at that time directed to the nature and resources of the vast territory which had been ceded to the keeping of the Hudson's Bay Fur Company, as there was a prospect of its being to some extent thrown open to colonization by the lapse of part of that Company's rights.

Principally through the efforts of Sir Roderick Murchison (at that time President of the Royal Geographical Society), General Sabine (acting for the Royal Society), Sir W. Hooker and Dr. Hooker, and of Mr. Ball (then Under-Secretary of State for the Colonies), the Expedition was organized and committed to the charge of Captain



Section No. 1. General Section from the Pacific Ocean to Hudson Bay on a N.E. line between Vancouver Island and York Factory. Distance 1400 miles. Vertical Scale eight times the horizontal.
Cascade Mountains
Columbian Desert.
Rocky Mountains.
Lake Winnipeg
Eastern Axis
Hudson Bay
Diagram-section of British N. America, shewing the Geological Structure from Vancouver Island to Hudson Bay
Cascade Mountains.
of the Strata at NANAIMO, from observed Sections.
Section of Canoe Route between L. Winnipeg & L. Superior.
Laurentian Axis
Lake Winnipeg
Hudson Bay
La Roche Percée
GEOLOGICAL MAP
of the Country between
LAKE SUPERIOR & VANCOUVER ISLAND;
By James Hector, M.D.
Routes of Capt. Palliser's Exploring Expedition
Terraced Shingle of West Slope and Glacial Drift and Lake deposits of East Slope
Miocene Lignite Basin
Eocene Marine (Cyprès Hills)
Upper
Cretaceous strata of the Prairies
Lower with Lignite
Disturbed Cretaceous strata of Rocky Mts. and Lignite group of Vancouver Island
Carboniferous Limestone.
Silurian of Hudson Bay, and Silurian of L. Winipeg.
Huronian of L. Superior, and Schists of Rocky Mountains
Metamorphic Rocks and Granite
Volcanic Rocks
The following AUTHORITIES are also consulted.
Meek & Hayden (Upper Missouri), Richardson & Hind (Winnipeg District)
Logan, Owen & Bigsby (L. Superior), Bauerman & Palmer (Cascade Mts.)
GEOLOGICAL SKETCH-MAP OF
NANAIMO,
Vancouver Island.
By James Hector, M.D.
Scale of Miles
Fossil Point
Greenstone
Green Sandstone with Trigonia
Newcastle Seam
Douglas Seam
Newcastle I.
Douglas I.
NANAIMO
Everywhere covered with dense Forest


Vertica
Lake Wi
Hudson Bay.
IMO, from observed Sections.
Mountains.
Vermillion Pass.
h Fossil Point. c. Gravel-stone with Wood. Islands off Fossil Point and
ft.) f. Douglas Coal-seam (4 ft.) g. Argillaceous Sandstones with
d: a Fault (?) k. Conglomerates and false-bedded Sandstones.
123° 50'
123° 45'
een L. Winipeg & L. S.
LOGICAL SKETCH-MAP OF
NANAIMO,
Vancouver Island.
By James Hector, M.D.
ian Axis
Scale of Miles
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Bank
5'
49°
7°
123° 50
123° 45'
J. W. Lowry fc.

Palliser, whose previous adventurous travels in that region had given assurance of the ability and energy necessary to penetrate unexplored country, and to preserve a friendly footing with the savage tribes that were to be encountered.

I was selected by Sir Roderick Murchison to accompany this Expedition in the combined capacity of surgeon and geologist; and, at the request of Government, he furnished me with instructions as to how I should turn to best advantage my opportunities for geological research.

The more important results of my work I have now the honour to communicate through him to this Society.

They have been accumulated during three years' travel in wild regions uninhabited save by Indians, or, at rare intervals, by little communities of persons engaged in the fur-trade. Excepting in the maps of Mr. Arrowsmith, which gave very correctly, on the whole, the great general features of the region explored, embracing 33° of longitude, and in some places 5° of latitude, nothing was known of its topography; so that this essential to sound geological reasoning had to be acquired step by step as the country was examined. I therefore submit my observations only as the best I could make under the circumstances, knowing that a re-examination of the country with the aid of the topographical details which we now possess would materially alter many of the views I have expressed.

Our previous knowledge concerning the geology of the interior of British North America was confined to the observations of Sir John Richardson, made during his three great overland arctic expeditions—the first two with Sir John Franklin, and the last in search of that lamented traveller. His published descriptions of the country he passed through are models of minute observation and cautious inference. To him we owe the first discovery of Silurian strata resting on a primitive axis stretching to the north-west from Lake Superior to the Arctic Ocean, and overlain by Devonian strata. He also showed the Rocky Mountains, where he met them on the Mackenzie River, to be composed of Carboniferous Limestone for the most part, which is also their character, we shall find, further to the south. From Elk River he brought home fossils which, although from a group of strata which he classes as Devonian, yet in a foot-note, on the authority of Sowerby, he says have quite a Jurassic aspect. That he was right in the latter suggestion is rendered probable by the recent publication of species of *Ammonites* by Mr. Hind, which were procured from that locality by the fur-traders, and which Messrs. Meek and Hayden consider to be of Jurassic age. Sir John Richardson also described the existence of a great lignite-basin in the valley of the Mackenzie River, which he classes as of Tertiary age.

The line of route, however, followed by Richardson did not, with the exception of the canoe-route from Lake Superior to Lake Winnipeg, and again at Fort Carlton on the Saskatchewan, touch on the country which has been explored by this Expedition. With regard to the canoe-route, I have added nothing to the researches of that traveller, and to the still more minute observations of Dr. Bigsby, which were some years ago communicated to this Society. In 1855 Mr. A. K. Isbister communicated to this Society a useful and concise recapitulation of what had been written concerning the geology of the Hudson's Bay Territories, without adding anything, however, to our knowledge of the central district with which I have principally to deal. It is to Mr. Hind alone, who was in command of the Canadian Expedition to explore part of Rupert's Land, that I can refer in confirmation of my observations in any part of the prairie-regions. Mr. Hind in 1858 partially travelled over nearly the same ground as that traversed by our Expedition during the previous summer, but only as far as the elbow of the South Saskatchewan, and in regard to all essentials our work agrees exactly*.

Mr. Hind's report is valuable from his having had his fossils examined by Messrs. Meek and Hayden, whose labours in the Upper Missouri country and Western States since 1852 have given us most of the knowledge which we possess concerning the classification of the strata composing the northern part of the great American prairies; and to those gentlemen I shall have frequent occasion to refer.

Concerning the mass of the country explored, consisting of the prairies within the British possessions and the Rocky Mountains between latitude 49° and 53°, and of the country westward to Fort Colvile, I am not aware of anything having been published, excepting a few general remarks collected by Richardson from the botanists Douglas and Drummond or from the fur-traders.

Concerning the geology of the Pacific Coast, in the neighbourhood of the 49th parallel, there are very interesting notes scattered through the various U.S. Senate-papers, by Mr. Gibb and Dr. Suckley, who were employed in the survey for the Pacific Railroad. The former gentleman is still working in that country, being attached to the North-west Boundary-Commission. There is also a short notice of the geology of Vancouver Island, by Mr. Bauerman, geologist to the British section of the same commission, published in the Geol. Soc. Journal for 1860.

GENERAL PHYSICAL FEATURES.

The prairie-country which I have principally to describe may be considered as forming the northern portion of a triangular space containing the plateau which occupies the central region of the North American continent, having for its sides, first, the Rocky Mountains; second, the Laurentian axis or "intermediate primitive belt" of Richardson; and third, the Alleghany Mountains.

A low indistinct water-shed 850 feet above the sea at its lowest point, and apparently undetermined by any disturbance of the rocky framework of this basin posterior to the deposit of its more unconsolidated contents, follows a line sometimes north and sometimes south of the 49th parallel of latitude (which is the Political Boundary-line), dividing the waters which flow to the Gulf of Mexico from those flowing to the Arctic Ocean.

* My first Report on the Geology of this district was dated December 14, 1857. See Parliamentary Papers, June 1859.

The route of the Expedition starting from Lake Superior, after crossing a spur of the eastern axis, traversed the northern part of the plateau to the Rocky Mountains, and thence down the western slope of the continent to the Pacific Ocean.

The Mackenzie River, rivaling in its proportions the Upper Mississippi, breaks the apex of this triangle, escaping through the Rocky Mountains to the Arctic Sea; while the Saskatchewan and other rivers of the southern British territory dilate into great lakes at the western base of the Laurentian axis, through which they then escape to Hudson Bay.

The Laurentian axis of metamorphic rocks with its fringe of Silurian strata may be considered as stretching from Western Canada to the Arctic Ocean, near the mouth of the Coppermine River, in a N.W. direction; but it sends off a spur, which encircles the western shore of Lake Superior, and loses itself under the prairies of the State of Minesota.

Lake Superior and Lake Winnipeg, according to the surveys of the Canadian Expedition, have nearly the same altitude of 600 feet above the sea, while the rocky district that separates them has double that elevation, or 1300 feet, above the sea; but this is in many places increased to 1600 feet by the deposits of drift that will be hereafter described.

The highest point of the great plateau that is in British territory is to be found when, at the base of the Rocky Mountains, that chain is intersected by the 49th parallel of latitude, where it is elevated 4300 feet above the sea. If followed into the United States to the south, it is found to reach a still greater elevation along the base of the mountains, until it merges with the great table-land of Mexico, which has an altitude of 6000 feet. From the above point of intersection to the nearest point of the Laurentian axis, which is a line from near the source of Belly River in a N.E. direction to Cumberland House on the Saskatchewan, the distance in an air-line is over 500 miles, and the difference of elevation of these two points gives a mean slope of 6 feet in the mile. The general level of the eastern base of the Rocky Mountains also declines rapidly to the north; for in latitude 51° 9′, at where the Bow River emerges on the plains, the elevation is 3900 feet, and at where the Athabasca, the most southern tributary of the Mackenzie, leaves the chain in latitude 53° 12′, it is only 3300 feet above the sea*.

The slope of this plateau is, however, far from being uniform, but is broken by steppes which have been formed by the erosion of the surface of the country, and which indicate different grades in the elevation of the continent during later epochs. These steppes are boldly marked, sometimes increasing the altitude of the prairies,

* As the Rocky Mountains are cut through by valleys almost to the depth of the plateau on which they stand, this depression of the chain towards the north has a remarkable influence on the climate in some localities, especially mitigating the severity of the spring months by admitting the influence of the mild climate of the western sea-bord at a time when the eastern part of the continent in the neighbourhood of the great lakes is still icebound.

as the traveller follows a westerly course, by an abrupt rise amounting to 600 feet. They have a very irregular outline, and are cut through by the river in many cases, so as to form isolated masses of broken table-land. (See general section: Sections Nos. 1 & 2, Pl. XIII.)

The Rocky Mountains forming the western limits of the great plateau rise from it very abruptly, the eastern ranges often presenting sheer cliffs 2000 to 3000 feet in height. These are, however, cut by transverse valleys into which the superficial deposits of the prairies penetrate, and have been preserved, more or less perfectly, as terraces in the mountain-valleys.

The mountains formed of broken plications of strata, as will be afterwards described, are disposed in parallel groups, the great valleys in the length of the chain generally occupying anticlinal fractures. The flexures have been more perfectly developed in the eastern part of the chain than towards the central parts, where the mountains have a massive cubical aspect, the strata having been fractured and upheaved rather than bent by disturbing agencies. This is owing, no doubt, to the mineral composition of the strata, and not to any modification of the disturbing force; for, as the western slope is descended, slaty rocks are met with, which again present perfect flexures. The mean altitude of the Rocky Mountains between latitude 49° and 53° is about 12,000 feet above the sea, but there is a very singular absence of marked peaks. The chain culminates in latitude 52°, where the mountains are very massive and are traversed by profound valleys, the heads of which are occupied by glaciers.

From the Rocky Mountains to the Pacific Ocean the country is extremely rugged, resembling similar Silurian and metamorphic regions in other parts of the world. It forms a great trough, bounded to the west by the Cascade range of mountains, which closely hugs the Pacific coast in this latitude. This range, which is only rarely broken by valleys, and those of comparatively recent date, runs like a wall 4000 to 5000 feet above the sea-level. At intervals there occur great conical mountains, such as Mount Hood, Mount Baker, and others, which rise to 10,000 or 12,000 feet, and from their isolation, being perfectly unconnected, except by the lower range, they present a very grand appearance when viewed from the coast. Owing to the great fall of the rivers, the narrow valleys, and the rapid erosion having continually carried on the rearrangement of the superficial deposits, the grades in the elevation of the continent cannot be so well discerned on the western slope as on the eastern, although these deposits are found to be greatly developed.

After this brief sketch of the physical features of the country, I now proceed to describe the different strata, reversing the order of their deposition.

SUPERFICIAL DEPOSITS.

These are very extensively developed in every part of the region explored; and their classification involves very interesting conclusions respecting the changes of level of the continent, both posterior and anterior to the great northern drift.

Judging from the altitudes at which erratics are found to be dispersed, the continent must have been depressed at that period beneath a sea in direct connexion with the Arctic Ocean to the depth of nearly 3000 feet; and since then, during its gradual emergence, this region of North America has received its present form of surface by denudation,—first, as effected on seacoast-lines, and latterly by the coast-lines of great inland lakes, which, it will be shown, though still existing, were previously of much greater dimensions.

The superficial deposits during and posterior to the Drift are so different on the opposite sides of the Rocky Mountains that they must be treated of separately, whilst those anterior to that epoch will be found to have a common character.

Terraces of the Lake Superior Basin.—In ascending the Kaministoquoia River for a considerable distance above the Kakabeka Falls, the country is covered by a deposit of red marl-earth which forms the high terraces of the river. Thus opposite to the mouth of White Fish River there are three distinct terrace-levels of 20, 60, and 90 feet. At some distance back from the river still higher terraces occur, belonging to this class of deposits, which must be considered as of more recent age than the true drift. Sir William Logan describes one at the height of 331 feet above Lake Superior. The great deposits of sand and gravel which rest on the highest levels of the axis, and are first met with at Dog Portage, belong, I think, to the period of the Drift, and will be referred to in the next group.

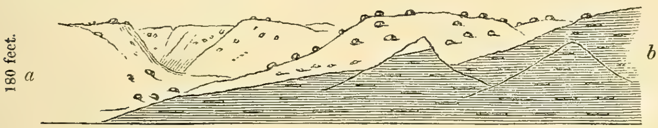
Superficial Deposits of the Central Plateau.—The steppes of this great slope may be naturally divided into three groups having different ages and circumstances of deposition, and boldly marking three distinct *Prairie-levels.* (See Sect. No. 2, Pl. XIII.) To the most recent of these belong the low prairies which surround Lake Winnipeg and the lakes of that group, including the marshy country to the west of Manitoba Lake. This forms the *First Prairie-level.* In the vicinity of the Red River Settlement, its composition is of argillaceous marl, with a deficiency of sandy matter, and it is invariably stratified in thin layers. Underlying this at various depths from the surface, is a bed of stiff clay, which forms the immediate margin of the river at many places. The upper layers of this deposit contain leaves and fragments of wood and reeds, and the whole is undoubtedly a freshwater deposit, indicating a time when the Winnipeg group of lakes covered a much more extended area than at present, the gradual deepening of the rocky channels through the eastern axis having increased the drainage in modern times.

The surface of this deposit is about 75 to 100 feet above Lake Winnipeg, but it slopes gradually from the west, and at Pembina Mount, near St. Joseph, is at least 100 feet higher. To the east of Red River, in descending the Winnipeg River, two well-marked levels were observed which belong to the group of extended lake-deposits. Thus below the Seven Portages that river flows through a smooth channel, and the banks are composed of a white marl-earth; the river being at first only slightly depressed, but soon from its rapid descent, while the level of the deposit remains the same, the banks become high. At the Rat Portage, this terrace, which is 150 feet above Lake Winnipeg, retires from the river on each side, and is replaced by another at an altitude of only 75 feet, through a cutting in which the river flows to its mouth at Fort Alexander. This ancient lake-bottom extends south of the 49th parallel into the American State of Minnesota, and everywhere presents a rich level prairie, only broken by slight gravel-ridges which have formed shoals in the ancient lake, or by patches of the magnesian limestone beds which crop out into the plain, such as at the Stony Hills, east of Fort Garry, which must have been a rocky island at one time.

The banks of the lower part of Rainy River are composed of rich alluvial deposit of a light-grey colour, containing a large proportion of white sand. It is distinctly stratified, and has without doubt been formed by an extension of the Lake of the Woods back towards Rainy Lake. In the upper part of Rainy River, the banks are high and terraced, and boulders show that at this level there is also a deposit of true Drift.

At Pembina Mountain, the eastern limit of the *Second Prairie-level* forms an escarpment measuring 250 feet above the plain at its base. From the point where it crosses the 49th parallel, it sweeps to the north-west and assumes a more gentle slope, being broken up into three or four subsidiary terraces. It then meets the Assineboine River near the mouth of the Souri, and is continued to the north by the high grounds that lie to the west of Manitoba Lake from Riding Mount to the Basquia Hills, which, however, rise to the full height of the level—that is, to 1600 feet above the sea. Below Fort à la Corne the banks of the Saskatchewan are described as suddenly becoming reduced from the height of several hundred feet to a slight elevation above the river, showing that it is at that place where the eastern limit of this level meets that river. The prairies of the Upper Assineboine, the Qu'appelle River, and those along the Saskatchewan, from Fort à la Corne to the elbow on the south branch, and also up as far as the longitude of Fort Pitt on the north branch, all belong to this level, which also extends to the base of the Great Missouri Côteau. The mineral composition of the superficial deposits of the Second great Prairie-level is very different from that of the first. Sand is the predominating ingredient. Thus at St. Joseph, where the banks of the Pembina River present a fine section of it to its base, the material is a coarse red sand, with gravel and boulders. There are no signs of stratification in any part of this deposit as seen at Pembina Mount, but further west, where it assumes a light-grey colour, and contains a considerable quantity of lime, it is imperfectly bedded. Near Fort Ellice, and at many other parts of the district to the south and west of that place, this deposit is formed wholly of fragments of the underlying Cretaceous shales. At Long River, Forked Creek, and many other places, this deposit was observed to form only a very thin coating to the Cretaceous rocks. Notwithstanding that the prairies of this level are often cut to a great depth by the rivers and creeks, very little can be learnt of its nature at different points, as slides in the banks of the gulleys are rarely seen. At Fort Ellice the valley of the Assineboine is 240 feet deep, and about 100 feet of that is composed of this drift-deposit resting on the Cretaceous beds. In the Qu'appelle Valley, near the Mission, a slide exposed the deposits beneath the plane to the depth of 250 feet, showing it to be composed of stiff sandy clay of light-red colour, with patches of blue clay and gravelly beds. On the whole, the character of this level, as far as regards its mineral composition, is variable and local. Boulders are tolerably plentiful all over its surface, but occur in greatest quantity on the sides and summits of ridges and mounds, which rise in groups to the height of from 50 to 80 feet. Immense outliers of a still higher level occur, attesting the immense denudation which has taken place; these generally rise from 1400 to 1600 feet above the sea, which latter is the height of this level at the base of the Grand Côteau, Eagle Hills, and Thickwood Hills, all of which form the eastern limit of the next great steppe. (See fig. 1.)

Fig. 1.—*Section* 16 *miles above the Elbow of the South Saskatchewan, showing the junction of the Drift and the Cretaceous clays at the base of the Third Prairie-level.*



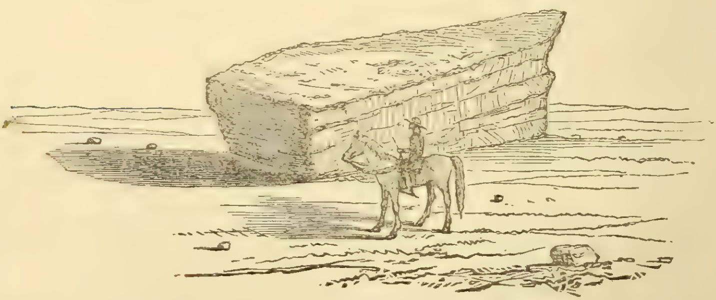
a. Drift. *b.* Septaria-clays (Upper Cretaceous).

These outlying patches occur along two lines parallel to the general contour of Lake Winnipeg and that of the next higher level to the west, and were doubtless continuous ridges until cut through by the different river-valleys. Thus overhanging the lakes, we have the Pas, Porcupine, Duck, and Riding Mounts; and to the west, a line of which the Touchwood Hills, Moose and Turtle Mountains form the principal points. These have all a common character, rising gently to an ill-defined table-land from the west; while their eastern aspect is extremely rugged, presenting irregularly deposed ridges of coarse sandy drift highly charged with boulders. This steep escarpment is generally densely wooded, and encloses numbers of small lakes.

The eastern limit of the *Third great Prairie*-level is met with at the Grand Côteau, Eagle Hills, and Thickwood Hills, and is only cut through by the channels of the north and south branches of the Saskatchewan; while all the other rivers of the eastern plains, such as the Souri, Assineboine, Qu'appelle, &c., have their sources short of it. I have stated the prairie at the base of this *third level* to have an elevation of 1600 feet above the sea, and a depression of the continent to this extent would be sufficient to submerge the eastern Laurentine axis between Lake Winnipeg and Hudson Bay, or at least to convert it into a mere chain of islands. The eastern coast-line would then leave the Rocky Mountains in latitude 56° N., near Peace River, and would follow what is now the water-shed between the Saskatchewan and the rivers more to the north, till it reached the 107th of longitude. From this point the Thickwood Hills, Eagle Hills, and Thunder-breeding Hills would form the headlands of a great bay into which poured the waters of the two Saskatchewans, at that time independent rivers debouching where they now make the acute bends known as their "Elbows". The coast-line was then continued to the south-east, forming the *côteau* that dips between the Missouri and St. Peter's Rivers. As seen from a distance when travelling in the low plains, this great steppe appears as a range of blue hills with a smooth undulating outline. On approaching it a gentle ascent is accomplished for many miles, after which an abrupt rise of from 400 to 600 feet has to be effected, generally in from 4 to 6 miles. The surface of the slope is extremely rugged, and has evidently been worn into pot-holes, ridges, and conical mounds by the action of water on the soft clay strata of the Cretaceous group. Everywhere the slope is thickly strewn with boulders, all derived from the Laurentian chain to the east, or from the Bird's-eye Limestone which rests on the western flank of that axis.

Near the elbow of the North Saskatchewan a remarkable group of boulders of this kind of limestone, of enormous size, crosses the country in a line parallel with the *côteau* to the west. This line has been observed at points 30 and 40 miles apart. They occur as great angular masses, consisting of several of the beds of limestone, the coherence of which being very slight proves that they must have been stranded without any great violence. One of these masses contains over 3000 cubic feet of stone, and rests on the plain obliquely with its south-western angle buried in the soil (see sketch, fig. 2).

Fig. 2.—*Boulder on the Plains south of Carlton.*



More to the west than this is a line of sand-hills, which has evidently marked a coast-line, although their original position may now be much altered, since they are still wind-blown as during their first production. They have a clear relation to the ancient level, and are found at the same altitude over such a stretch of country, always at a little distance from the base of the escarpment, that there can be no question as to their origin. Similar sand-hills were observed on the Souri River at the base of the Second Prairie-level, which must have been formed on the shore of the extended lake.

The resemblance which the plains along the base of this great steppe bear to the shore of Hudson Bay at the present time may be judged of from the description given by Sir J. Richardson, who says, "The western shore of Hudson Bay between latitude 56° and 58° is flat, and the depth of the sea decreases very gradually on approaching them. In seven fathoms of water the tops of the trees are just visible from a ship's deck. Large boulder-stones strew the beach, and form shoals even at the distance of five miles from the shore, which are very hazardous to boats." In proceeding up the river from this coast, he says that after a tract of level country "the banks" (consisting, he before mentions, of drift-clay and boulders) "rise from a very narrow river-channel to an elevation of very nearly 200 feet. Their outline is broken into conical eminences by short ravines, which open into the river at right angles. These banks have exactly the same form and constituent parts as those which occur on the confines of Lake Winnipeg and the Saskatchewan." As he made the latter remark in allusion to the nature of the underlying rocks at the two localities without reference to the drift, it is all the more valuable for the purpose of proving this similarity, which is so striking between the present state of the coast of Hudson Bay and the ancient coast-line along the base of the Third Prairie-level. In the rugged district of this steppe there are enclosed numerous lakes, some of great size, and all, without exception, more or less impregnated with salts, of which sulphate of soda is the predominating ingredient. In autumn after the dry summer, these lakes are fringed with crystals, and the soil in many places is covered with a white efflorescence. Whether these salts are derived from the superficial deposits of the ancient coast-line or from the Cretaceous clays, I am unable to say; but the position of the salt-lakes, generally at the same altitude, inclines me to the former opinion.

The Laurentian axis is covered with a great deposit of drift, consisting of coarse red sand, with many large and small boulders. This deposit forms a flat swampy plain, well wooded towards the west, but towards its eastern margin, as at Cold Water Lake, worn into deep dry gulleys and round pot-holes without any exit. The thickness of this deposit is from 200 to 300 feet, and the highest point of it is about 900 feet above Lake Superior, or on a level with the plains near Carlton. Glacial scratchings were distinctly seen at many parts of the axis. The direction is generally north and south. Hardly a surface in the granitic tracts did not present distinct scratches. They were seldom, however, to be observed on southern exposures of rock-surfaces if these sloped much; but the more surfaces with northern exposures sloped, the better they seemed to be marked.

As will be seen from section No. 2. Pl. XIII., in rising to the surface of the third steppe we have the plains composed of the Cretaceous strata with only a very thin coating of Drift, which has always a local mineral composition, corresponding with that of the underlying strata, without admixture of materials carried from a distance further than a sprinkling of erratic blocks, of small size, and only to be found crowded on favourable spots.

These consist almost entirely entirely of fragments of metamorphic rocks, limestone being very rare.

I have not remarked the ordinary erratics at a greater altitude than 3000 feet; but at 3700 feet above the sea and 50 miles from the Rocky Mountains, there occurs a very extraordinary group of blocks of granite, resting on a high plateau formed of sandstone strata. These blocks are of great size, one having been estimated to weigh 250 tons. Although lying in a line miles apart, they seem to consist of the same rock—viz. a mixture of quartz and red felspar, the latter predominating, with only faint traces of mica disseminated in very minute flakes. They present smooth surfaces, although in general they are rhomboidal in form. Some of them are cracked into several pieces, which are quite detached, but are evidently parts of the same block*.

If these blocks were derived from the granitic belt to the east, as I believe all the erratics of the prairies have been, they must have travelled at least 400 miles. From the fact, however, that they are beyond the western verge of the Drift, and that the boulders were found, as a rule, to diminish in size in that direction, it may be that the presence of these blocks is due to very different agencies,—different, at least, in the time of their occurrence. No granite was observed on the east flank of the Rocky Mountains within British territory, but the Trois Butes, south of the 49th parallel, are said to be composed of granite, and also the Black Hills; but both of those localities are much to the south of where those blocks occur.

The surfaces of the higher plains are in some localities traversed by profound rents, resembling the valleys of great rivers, but which, after running for several miles, are generally found to be closed at both ends. They are often occupied by deep lakes of salt water, depressed 200 feet to 300 feet below the plain, and from 500 yards to a mile in width. The great *coulées* in the neighbourhood of the Ear Hills, south of Battle River, are the best examples of these; but they are found in many other localities. It is difficult to conceive that they are due to erosion alone†.

Before leaving the superficial deposits of the prairie-country, it is necessary to notice the great river-valleys which traverse it, and

* For mention of a similar phenomenon, see Hooker's 'Himalayan Journals,' vol. i. p. 201.

† The ravines mentioned by Sir Charles Lyell in his Second Journey in the United States, p. 25. vol. ii., as occurring in the cretaceous and tertiary strata of Georgia, seem to be very similar to them. He says, that when the woods are cleared from the country, the sun, acting on the unprotected surface of the argillaceous strata, produces cracks that are soon enlarged to great gulleys by the torrents of rain that fall. We may suppose that on the Saskatchewan, where there is only a small quantity of rain, the winter's frost effects the same result, but with this difference, that the successive landslips, remaining unmoved, at last form such a gentle slope that vegetation can retain its hold, so that the rent is finally represented by a symmetrical valley.

which all point to a time when the rivers exercised a more powerful influence than now; as even small streams, such as Battle River, flow through valleys from 150 to 250 feet deep, which have been partially refilled with stratified deposits. The sides of these valleys are in general as regular and formal as those of a railway-cutting, excepting where the nature of the strata causes frequent slides, or harder beds give rise to a cliff-structure. The flat alluvial bottoms of these valleys are often four or five times the width of the river which winds through them, and which is hemmed in by secondary banks 30 to 40 feet high. The silt and alluvium are in general regularly stratified, and almost every river-point contains one or more lagoons, showing the frequent, though slow, change in the river-channel.

Terrace-deposits of the Mountains.—At the distance of 90 miles from the Rocky Mountains, the valleys of the rivers flowing to the east commence to exhibit terraces composed of rounded fragments of quartzite and limestone, such as would form the rounded shingle on a rocky shore. At the Rocky Mountain House, where these terraces first attracted my attention in the winter of 1857-58, the North Saskatchewan has excavated a valley in the Cretaceous strata, which varies greatly in its width, sometimes being hemmed in by perpendicular cliffs of sandstone, and sometimes sloping gently back to the elevated country on either hand where the strata had been less able to resist the erosion.

In this valley there are three terraces extensively developed at 20, 60, and 110 feet above the water-level*. Until we approach close to the mountains these terrace-deposits are confined to the valleys of the larger streams, but gradually they spread out, and at last cover the whole country along the base of the mountains, filling up the hollows and valleys of the outer ranges to the depth of several hundred feet. This feature was observed at every point where we approached the mountains from the east, from the 49th parallel northwards, and indeed was even better marked on the Athabasca River than on any of those further south. Judging from the accounts of American explorers, these terraces extend along the base of the Rocky Mountains all the way south to Mexico.

One hundred miles east of the mountains, in latitude 49° 30′ N., shingle-beds are found to cap the Cyprés Hills, which have an altitude above the sea of 3800 feet, or nearly the same as that of the base of the Rocky Mountains. The Cyprés Hills are nothing more than the western extremity of the great Missouri *côteau*, which, curiously enough, here presents an escarpment to the west, and is separated from the mountains by a tract of flat arid country of the above width. This *côteau* is composed of Cretaceous and Tertiary strata, which have remained as a dividing ridge, from the denudation having acted to the north and south of the line which it marks. It is on the west and south exposures of these hills that the shingle occurs, formed into terraces like those along the mountains.

These are not to be classed, however, with the river-terraces, which

* These are roughly introduced in fig. 7. p. 424.

are of much more recent formation, having been derived from the deposits along the base of the mountains *.

This may not only be inferred from their relative position, but also from the composition of the terraces themselves; for, although the pebbles are the same in all, those in the valley-terraces are well cleaned and mixed with sand, while in the terraces along the mountains and on the Cyprés Hills they are often encrusted with white calcareous matter. This sometimes increases so as to form a perfect cement, so hard as to allow of the fracture of the pebbles before that of the matrix, just as is seen in some ancient conglomerates †.

On approaching the Rocky Mountains the extreme regularity with which these deposits have been terraced by retiring waters at once attracts attention. At the place where Belly River leaves the mountains, in latitude 49° 34′ N., Capt. Blakiston measured three of these terraces, and found that they were elevated 61, 152, and 202 feet above the river-level, which at that point, according to his measurement, is 4024 feet above the sea. He describes them as being "very marked, appearing as a succession of steps from the level of the river to the plain above, often in sight for miles and running horizontally. The tread of the step is of variable width, but the rise is nearly always abrupt and well marked." From the regularity of these embankment-like terraces in the valley of one river, he named it Railway River (Further Papers, Palliser's Expedition, 1860, p. 68).

On Bow River they are also well marked, and there I measured four at the altitudes above the river-level of 30, 140, 170, and 240 feet, and traces of one still higher at 350 feet. The valley of Bow River within the mountains is narrow and tortuous for the first twelve miles, and in this part of its course the terraces are hardly preserved. Above this point, where it occupies one of the expanded horizontal valleys conforming to the strike of the strata, they are again enormously developed. Even on gaining the Vermilion Pass the only steep climb is at first, up the face of these terraces for 150 feet; and then a gentle slope leads to the height of land.

The valley of the North Saskatchewan is much wider and more direct within the Rocky Mountains; and there we have not only these terraces remarkably developed, but also their mineral composition much altered, partaking of what will be found to be their character on the western slope of the mountains. At a similar place, with respect to the mountains, to where the terraces were measured on Bow River, four were estimated to have an altitude of 25, 70, 180, and 300 feet above the North Saskatchewan. The shingle, cemented into a hard conglomerate, was here seen to rest on the edges of the contorted strata of grit and shale with thin

* In latitude 42° at the base of the Rocky Mountains near Fort Laramie, Hayden describes similar "deposits of coarse conglomerate, 50 to 150 feet in thickness, formed since the scooping out of the present river-valleys."—Proc. Acad. Nat. Sci. 1858.

† Darwin says of the shingle-formation of Patagonia, "The pebbles are imbedded in a white, gritty, calcareous matrix very like mortar, sometimes merely covering with a whitewash the separate stones, and sometimes forming the greater part of the mass."—Geol. of S. America, p. 19.

seams of coal. Within the mountains the terraces expand so as to form level prairies along the North Saskatchewan, of which the Kootanie Plain is the principal. It is many miles in extent and composed of shingle and incoherent sand, the widest terrace being 100 feet above the river. The river is, however, skirted by terraces at still higher levels, especially on the south or right side of the valley. Above Pine Point the calcareous matter of these terrace-deposits so increases as to replace altogether the pebbles, and they are often composed of fine gritty calcareous mud of glistening whiteness. If followed into the higher valleys, they become confused with the detritus of ancient glacier-moraines, which, however, are easily distinguished by the angular blocks which they contain.

On the Athabasca River, at fifteen miles from the mountains in a direct line, the terraces were found at 15, 100, 210, and 370 feet above the river-level. Within the mountains, this valley, which is more dilated than even that of the North Saskatchewan, has also the terraces better developed than I have elsewhere observed them on the east side of the chain. The river moreover dilates into extensive lakes at different points of its course, and there the rearrangement of the material of the terraces is seen to be going on; the water separating the calcareous mud from the pebbles, while the winds, which are extremely violent in this valley, sift out the fine sand and pile it in tracts of sand-dunes which cover large areas.

The terraces may be considered as ranging on the east side of the Rocky Mountains from 3500 to 4500 feet above the sea. Wherever they prevail they support a growth of a peculiar sturdy pine which, in common with the Banksian Pine, is known to the Hudson Bay Company's hunters as the Cyprés *.

Often the surface of a terrace is quite free from timber, the trees being easily thrown out of the loose gravelly soil, and then it is generally clothed with "bunch-grass †," which at once catches the eye as different from the grasses of the eastern plains. The country occupied by the terraces is easily passed through, as the forests are there free from underwood, and the only obstacle to the traveller arises from his having so often to make a steep descent to the base of the deposit, which is cut through by every little stream, and then to climb again the opposite bank. When passing along the side of a valley, the numerous cross gulleys due to this cause would render the construction of a road a very difficult matter, although nothing could be firmer or more level than the surfaces of the terraces themselves. This remark applies equally to the valleys on the west side of the Rocky Mountains, where the terrace-deposits have a much greater development.

Terraces of the Western Slope.—All the valleys between the Rocky Mountains and the Pacific coast lower than 4000 feet above the sea

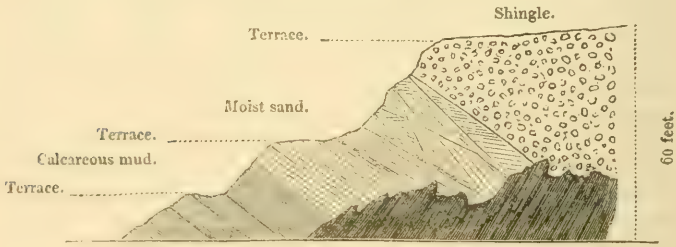
* This pine is allied to the *Pinus inops* of the Atlantic bord and to the *P. contorta* of the Pacific, and yet has distinctive characters from either. It has been proposed to call it *Pinus Saskatchewensis*, Hooker.

† *Festucæ* of various species. The grass on the eastern plains consists of varieties of *Chondrosium* (Blodget's 'Climatology of the United States,' p. 451).

are found to be more or less occupied by deposits which are terraced with greater regularity.

On descending the western slope, these deposits were first observed in the lower part of the valley of Vermilion River, where they are formed of the same glistening, white, calcareous mud that was seen in the valley of the North Saskatchewan; but it is in the wide valleys of the Kootanie and Upper Columbia Rivers that these terraces are best developed in the Rocky Mountains. These rivers run in opposite directions through the same great valley which lies parallel with the mountain-axis for nearly 250 miles, and which throughout is skirted by terraces forming a succession of platforms, often rising to 600 feet above the river. These extend into the side-valleys, preserving their horizontal character, but their composition is often changed. At various points these deposits were seen to be distinctly stratified, and in some cases they must have been disturbed between the time of their formation and that of their being finally moulded into terraces. Thus where the Kicking-horse River joins the Columbia, and where both valleys present perfect terraces at five different levels, the highest, forming a wide shelf 540 feet above the river, the appearance which is exhibited in fig. 3 was observed, where the stream has worn away the bank.

Fig. 3.—*Terraces in the Valley of Kicking-horse River, Rocky Mountains.*



The erosion of these deposits, and the production of steep and quickly succeeding terraces (both being processes which may have been simultaneously effected on successive shore-lines either of the sea or of inland lakes) have been much more perfect in the valley of Columbia, as far south as latitude 51°, than in the remainder of the Columbia valley, which extends for a degree further to the south, or throughout that portion of the same great trough which is occupied by the Kootanie River; for there the deposits remain comparatively undisturbed, and form great stretches of prairie, only cut through by a narrow but deep channel for the river. The change of appearance in the valley from this cause is very abrupt and striking. North of latitude 51° the terrace-steps succeed one another rapidly, with the *tread*, or horizontal surface of the step, narrow and furrowed; and the traveller's progress is here impeded by the dense growth of forest of a northern type, consisting of varieties of Spruce-fir for the most part, with dense underwood; but on passing south of the slight bend of the Columbia, the *tread* of the terrace-steps commences to expand into wide level plains, dotted with a forest of the sturdy *Pinus ponderosa* or the gigantic *Larix occidentalis*, both of which are trees that find their maximum in Southern Oregon. The outlines of the terraces still preserve the same extreme formality and steepness of slope, but on their level surface a rider can gallop in almost any direction, so free is the forest from underwood. Sometimes the trees are entirely wanting, leaving great tracts of open plain embosomed in the mountains, forming the camping-grounds of the Kootanie and Flat-head Indians, on which they raise the large bands of horses for which they are famous amongst all other Indians, the dry soil and nutritious bunch-grass producing a breed of superior hardihood and swiftness.

In descending the Kootanie River from the Tobaco Plains * to Colvile the country is rugged in the extreme, and these terraces are met with wherever they have been sheltered from recent erosion in valleys of unusual width or in recesses of the more narrow ones. On reaching the belt of country where schistose and metamorphic rocks prevail, the pebbles are often composed of greenstone, quartz, and the other vein-rocks of the strata which they overlie. On reaching the lower part of the country near Colvile, the terraces are still found in all the valleys, not only at moderate elevations but also high up in the mountains. Thus the Columbia at Fort Colvile, in latitude 48° 34′, is 1000 feet above the sea, and terrace-deposits were observed on the sides of the valley at least 1200 feet above the river-level.

The great Columbian Desert and the Spokane Plain are both covered with the same deposits of shingle, resting, in the former case, on the great lava-floes, and, in the latter, on granite and metamorphic rocks. The Spokane Plain, which is of comparatively limited extent, has its margin beautifully terraced, repeating on a grand scale the same phenomena as may be observed on the shore-line of a shallow lake after the summer-drought. At old Walla Walla, where the Columbia River passes from a wide and flat sandy desert to break through the profound rocky *cañon* of the Cascade Range, the whole country is covered with light blown sand, which renders it almost uninhabitable, being swept in clouds by the high gales that constantly blow either up or down the river through this wonderful chasm. Here in an ancient lake-bottom have been found the remains of a *Mastodon* by some American explorers.

To the west of the Cascade range of mountains along the Pacific coast, terraces of shingle prevail as in the interior. Also on Vancouver Island they were observed near Nanaimo. Near Fraser River and Puget Sound they are very well marked, and at the latter place occur the "Mound-prairies," which, however, I only know of by report. These are level surfaces of terraces free from forest, and covered with lines of conical mounds, 10 to 20 feet high, said to be formed of

* The term "Tobaco Plain" should proper'y be only applied to a little plot near the Kootanie Trading Post, but we have thought it advisable to extend the name to all the large plains along the Kootanie River near lat. 49° N.

boulders piled on one another and resting on the surface of the shingle.

Terraces in California.—Before leaving these shingle-deposits, which are so largely distributed throughout the mountain-valleys of British North America, I may mention that in California I found these terraces ranging on the western slope of the Sierra Nevada, at least to the height of 3000 feet, and there they are extensively worked by the hydraulic method for the sake of the gold they contain. At Nevada City, and also on the Yuba River, I saw deposits of this shingle-conglomerate, 200 and 300 feet in thickness, actually being washed off from the face of the country by this powerful means, which consists in delivering water under great pressure against the face of the cliff, from nozzles like those of a fire-engine. The supply of water for this purpose is in the hands of companies separate from those that conduct the mining, as it is often brought through tunnels and over high-level aqueducts from remote and uninhabited regions. The particles of gold are disseminated throughout the whole deposit, but the richest washings are from its base, where a pink pipe-clay, technically known as "pay-dirt," rests on the "bed-rock." The whole water, with the material washed out of the cliff, is directed through long troughs called "flumes," which are constructed of wood, like mill-leads, often continuously for six or seven miles. The large stones are thrown out, as they pass, by men with shovels, to save the wear on the bottom of the "flume," while the finer material is carried on by the rush of water, and passes over frequent cross bars called "ripples," where a little mercury is placed to entrap the gold by amalgamation. At Nevada City, where the coating of shingle-deposit has thus been cleared from the surface of the coarse-grained and soft granite which underlies it, gigantic masses were exposed on what had once been the rugged shore of an inlet, just as may be seen on a waterworn coast of the same material at the present day. In California fragments of wood are found throughout the shingle in abundance, often carbonized, but in general silicified into a substance exactly resembling asbestos. In the sand and conglomerate of the Kootanie Valley I found fragments of wood of similar appearance.

As my observations in California should not properly be introduced in this paper, I shall leave them for another opportunity, the object of my having mentioned them being to point out the great similarity between the superficial deposits of the great gold-country and those within the British territory further north, which encourages me to assert that the whole country up to the Kootanie River and the base of the Rocky Mountains, wherever the ancient terraces prevail resting on Silurian or metamorphic rocks, will be found to be auriferous. In my party in 1859 I had an expert "washer" who had been at the Californian mines; and he frequently got "colour," as a faint trace of gold is termed, by merely washing the gravel from the beds of the streams, without any regular "prospecting" or "digging." The discovery of what are among the richest "pan-diggings" on the Pacific coast in the Schimillcomeen Valley, and the existence of gold-mines worked since 1855 on Clark's Fork, half a mile north of the boundary-line where it meets the Columbian River, prove that the belt of auriferous country in California and Oregon is continuous with that of Fraser River; and there is no reason to doubt that in a short time the rugged and unexplored country which forms a triangular region north of the boundary-line, and is drained by the waters of the Upper Columbia and Kootanie Rivers will be overrun by prospectors, and then by active gold-miners, just as the western part of British Columbia has been within the last few years *.

Age of the Terrace-deposits.—The evidence we have respecting the age of the terrace-accumulations is very imperfect. There can be no doubt that those occupying the valleys of the Rocky Mountains, being furthest from the coast and at the greatest elevation, are the most ancient, and that from the time of their deposit till now the rearrangement of the same materials has been carried on during the gradual uprising of the continent.

The shores of the intricate channels and inlets on the Pacific coast of British North America, if elevated from the sea, would present but slight difference from sides of the narrow valleys in the Rocky Mountains at an altitude of 3500 feet. Whether the continent was ever in later times depressed to that extent in the mass, or whether the central upheaval has been much greater than that along its margin, is a consideration of great importance, and could perhaps be settled by ascertaining to what altitude the terraces can be traced on the Cascade Mountains.

The existence of marine Tertiaries along the coast, supposed to be of the same age as those in the eastern prairies, and also within the Cascade Range at slightly greater elevation and sometimes overflowed by the lava from those mountains, would seem to indicate that the elevation has been very unequal; or, in other words, that the Tertiary formations along the Pacific coast have hardly been raised at all, while those in the interior are elevated several thousand feet.

On the eastern plains we have marine and other Tertiaries at an altitude of about 3000 feet above the sea, and Hayden describes them as "in all cases undisturbed, and not unfrequently resting on the upturned edges of azoic and granitic rocks †." But in the prairies these Tertiaries, along with the Cretaceous strata on which they generally repose, have been enormously denuded, and are found merely as outlying patches forming the tops of hills. It must have been during the period when this denudation of the eastern plains accompanied the gradual emergence of the continent, but acting with very different results on the rocky sea-bottom and successive ranges of iron-bound coast presented by the western slope, that these immense deposits of shingle were formed and moulded into terraces ‡.

* I have just heard that some Americans have discovered that there is gold deposited by the Saskatchewan at the Rocky Mountain House. If so, it must be washed out of the shingle-terraces along the eastern base of the mountains.—Aug. 1, 1861.

† Proc. Acad. Nat. Sci. 1858, p. 17.

‡ In many cases there is no doubt that the terrace-arrangement has been

But if this reasoning is to apply to the most ancient of those accumulations, and so place them as more recent than the latest Tertiary times, then there must have been a slight depression prior to the steady and gradual elevation of the continent that has continued ever since. Moreover, unless this depression was local and confined to the mountain-region, how are we to account for the absence of Post-tertiary formations over the high-lying Tertiaries of the plains in sufficient quantity to have allowed time for the production of such a gigantic formation of waterworn stones?

On the other hand it is possible that their production may have commenced in Tertiary times, so that they are almost coeval with the great lignite-basin of the Missouri, which is an estuarine deposit resting, according to Hayden, quite conformably on his Upper Cretaceous beds.

He also describes his Titanotherium-bed, the lowest of the White River Tertiary basin, which has yielded so many forms of chelonian and mammalian remains, as likewise resting without a break of conformity on the Upper Cretaceous*. Thus if this latter suggestion respecting the age of the most ancient of the terraces be correct, they must have been formed in the straits and inlets of an archipelago or rocky reef lying to the west of a flat Cretaceous continent, in which were estuaries and lagoons choking with rank vegetation, and large lakes, which gradually filled up, burying the remains of the gigantic turtles and extinct forms of mammals.

In the Gulf of Georgia there are beds of conglomerate and coarse sandstone overlying the Cretaceous strata to all appearance, and which, I have thought, may perhaps correspond to the more ancient of the mountain-terraces to which they bear a great mineral resemblance, excepting that those in the Gulf of Georgia have been much disturbed, so that they are harder and their bedding is better marked. The difference is, however, not greater than we should expect, if we consider the one group to have been placidly raised to a great altitude, while on the other the force has been expended in producing plications and faults.

Drift of Pacific Coast.—The glacial markings on the metamorphic rocks of Vancouver Island are better displayed than I have elsewhere seen them. Every surface near Victoria that is either naturally exposed, or from which the soil has been removed, exhibits deep parallel furrows, generally with a N.E. trend. They are also seen on the main land at the entrance to Puget Sound quite as distinctly. Erratics are distributed all along the Pacific coast, at least as far south as latitude 46° N., where they occur, but not very plentifully, near Vancouver and in the valley of the Willamette. They are often of great size, and on Vancouver Island are composed of a grey

given to these deposits by the shore-line-action of lakes which formerly occupied the irregularities of the surface of the country; but we can hardly suppose that the material itself, consisting of smoothly worn fragments of the hardest rocks, could have been entirely the result of the feeble erosive agencies that such lakes exercise.

* Proc. Acad. Nat. Sci. 1858, p. 19.

syenite, which Mr. Bauerman told me occurs in the Cascade Range. Often in the woods to the south of Fraser River I saw solitary boulders 6 or 8 feet high, resting apparently on the shingle-terraces which here are only 100 to 200 feet above the sea. Certainly at the Fourth Plain, five miles from Fort Vancouver, there are several large blocks, though not of the above size, that do rest on the gravel-terrace which skirts the valley of the Columbia River. On most of the islands in the San Juan Archipelago, and along the coast of Puget Sound, high sections of yellow sand and clay are exposed, forming the sea-shore. The terraces are there further inland. From this drift Mr. Bauerman procured casts of *Cardium* and *Saxicava*.

As I never observed drift or boulders within the Cascade Range, even in places elevated only 600 to 700 feet above the sea, but as all the superficial deposits in the great trough between that range and the Rocky Mountains are clearly formed from the rearranged materials of the shingle-terraces along with tufas from the Cascade Range, I conclude that the average lowest altitude of the Cascade Range, which is somewhere about 4000 feet above the sea at the present time, exceeded the depression of the continent during the glacial epoch, and presented a barrier to the causes which transported the erratics and scratched the rock-surfaces along the Pacific coast. If the Cascade Range at that time formed a promontory enclosing a gulf like the Gulf of California, it would exactly fulfil these conditions.

TERTIARIES.

The existence of Tertiary* strata, ascertained to be so by their organic remains, has only been proved at one point west from the Cyprés Hills, where Mr. Sullivan obtained *Ostrea Veleniana*, associated with a *Modiola* and a few other fossils, which Mr. Etheridge, who has named all the Cretaceous and Tertiary fossils brought home, has been unable to identify. The beds from which these fossils were obtained consisted of friable sandstones with argillaceous and calcareous concretions, with massive and irregular bedding, and often passing into incoherent pebble-conglomerate. Judging alone from mineralogical resemblance, these beds were recognized over a considerable area, but always forming high grounds in the neighbourhood of the Missouri Côteau, S.E. from the mouth of Belly River.

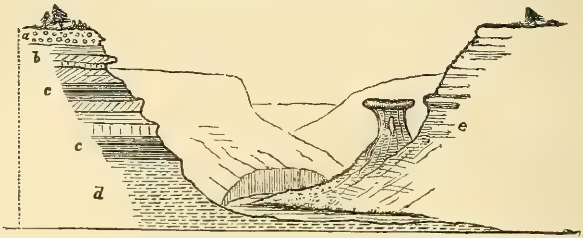
On the Souri River, seven miles north of the boundary-line, in longitude 104°, was observed what is perhaps a portion of the Missouri Tertiary lignite-basin. This locality, which is known to the half-breeds as " La Roche Percée," is well up the eastern slope of the Missouri Côteau, and within a degree of latitude of that river itself, at a point where the existence of the lignite of Tertiary age has been well ascertained.

The Souri River at this point flows through a valley with steep sides, depressed 165 feet below the surface of the plain, which at this

* Using the term in its limited signification, as including Eocene, Miocene, and Pliocene.

place is quite level, and strewn with an immense profusion of boulders, being at the base of the Third great Prairie-level. The sides of this valley are cut by numerous ravines, which only extend a short way back into the prairie, and exhibit sections of the following strata (see fig. 4):—

Fig. 4.—*La Roche Percée, in the Valley of the Souri River: a section of the Tertiary Lignite Group.*



a. Drift. *b.* Splintery limestone. *c.* Clay with lignite.
d. Coarse-grained sandstone. *e.* Concretionary sandstone.

a. Drift with boulders	4 to 7 feet.
b. Mud-stone	1 foot.
c. Incoherent sandstone, fine-grained, with hard concretions impregnated with iron, which weather concentrically	10 feet.
d Porous calcareous sinter	1 foot.
e Hard blue ironstone-shale, decomposing into deep orange-coloured splinters	2½ feet.
f Gritty limestone	2 ,,
g Ash-coloured clay in thin indistinct layers, very soft, with one bed of lignite 9 inches in thickness	8 ,,
h Hard blue limestone	
i Same as *g*, but with thin seams of lignite 10, 8, and 6 inches in thickness	15 ,,
k. Gritty limestone	2 ,,
l. Brightly coloured marls and shales, with selenite in small fragments	10 ,,
m. Coarse-grained, incoherent sandstone more than	20 ,,

Excepting a few fragments of plant-impressions, like stems of sedges, no fossils were obtained from these beds by which the age could be identified. They may perhaps be passage-beds, representing the highest strata of the Cretaceous era, overlain by the lignite-basin; as further south they are so disposed, and with very similar mineral characters.

The lignite does not occur in well-defined beds, but graduates into the shales on both surfaces. It is not visible until a light ashy deposit is removed from the exposed edge of the bed, which has been formed by the soft clay washing down from the strata above. The lignites are of several different varieties, some having quite the texture of compact cannel-coal of fine quality, some like the more glistening bituminous coal, friable, and only to be obtained in small cubical fragments, while some of it can hardly be distinguished from charcoal, but all varieties have a deep purple-brown colour, which is well seen when a portion is reduced to powder. A sample of this lignite has been analysed in Dr. Percy's laboratory, at the Museum in Jermyn Street, by Mr. Charles Tookey, with the following results:—

Carbon	56·50
Hydrogen	3·65
Oxygen	18·91
Nitrogen	0·80
Sulphur	0·60
Ash	5·62
Water (hygroscopic)	13·92
	100·00

The sandstone which forms bed *c* is composed of very fine pure grains of quartz, hardly cohering; but in the upper parts of the bed there occur concretions impregnated with clay and iron, and of a reddish hue, that are comparatively hard and decompose concretionally. This irregular disintegration gives rise to a curious formation of the banks of the valley, which has rendered this locality an object of great superstition among the Indians. The lower sandstone wears away from under the hard concretions, that assume the form of compressed spheres, and sometimes long cylinders like the boilers of a steam-engine, which are left supported on pillars of the white sandstone. The gulleys which join the main valley are thus filled with grotesque forms, sometimes exactly resembling the half-buried remains of ruined edifices. The sandstone (*m*) at the base of the section is also very incoherent, but is composed of larger grains of quartz. The strata are not found in the same order and proportion throughout the valley, but yet they always appear to be horizontal. The marly shales (lettered *l*) have a considerable quantity of selenite disseminated as small crystals. La Roche Percée is in latitude 49° 6′ N., and longitude 103° 54′ W.

This formation has, without doubt, been much more extensive, and has overlain the Cretaceous beds as far north and east as the great sandy waste where the track of the Expedition crossed the Souri River in latitude 49° 30′ N., and longitude 100° 20′ W. At that place the sand-hills rise 70 and 80 feet, so pure and so feebly bound by the few plants that grow on their surface that they are constantly windblown. Under these, and cut through by the River Souri, was observed a lacustrine deposit in which one bed was composed wholly of rolled fragments of lignite, overlain by sandy marls and gravel, enclosing fragments of bones which Professor Huxley refers to the Bison; and along with these were small land- and fresh-water shells. This deposit has been found in one of the lakes, which I referred to generally as of Quaternary age when describing the superficial deposits of the prairies. The origin of this one has been from the damming back of the water by the Blue Hills of the Souri, which are composed of hard Cretaceous shales, and through which the river of that name escapes to join the Assineboine by a narrow and profound chasm which it has gradually cut through the horizontal strata. The place where the sand-hills and the bed of lignite-pebbles is found has been the north shore of the lake, which must have been of very considerable extent.

The great valley of the South Saskatchewan where it is hemmed in closely by the Grand Côteau at its elbow opens out above that point, and at the junction of Red Deer River and Bow River in longitude 109° 30′ W., latitude 51° N., the hills retire many miles from the river, which, however, always preserves its immediate banks of from 200 to 250 feet in height. The prairies are there again covered with a waste of blown sand, which may perhaps have had a similar origin from Tertiary or Upper Cretaceous beds, which have been subjected to local denudation. The same iron-shot bands containing the shells of land Molluscs and Bison bones were there observed, but without any traces of the rolled fragments of lignite.

East from the elbow of the South Saskatchewan there is also a tract of sand-hills with quite the same feature; but there I observed masses of sandstone *in situ*, resembling the lowest beds at La Roche Percée. On the opposite site of the Qu'appelle Valley, within a few miles from where I turned, the same sandstone occurs, and there Mr. Hind found the characteristic fossils of the Upper Cretaceous group (Rep. Assineboine and Sask. Exp.).

On the North Saskatchewan, forty miles above the elbow and a little way above the Eagle Hills, on the left bank of the river, there are cliffs of a very incoherent sandstone, rising 40 to 60 feet above the water's edge, and worn into caves, which often communicate with the plain above. At the time I observed the sandstone, I took it for a local variety in the drift. If, on the other hand, it belongs to the Tertiary or the Upper Cretaceous group, it proves them to have a very singular distribution, conforming in a great measure to the present river-valleys; as on the opposite side of the river, at a little distance back, the Middle Cretaceous group rises to the height of several hundred feet.

Eight miles below the elbow of the same river, near Birch Gulley, the banks rise abruptly on either side to the height of 210 feet, when the level plain is reached at the point where the great erratic masses of limestone rest on its surface. At the base of the bank from this point, all the way down to Carlton, a distance of forty miles, springs of water escape highly charged with iron and lime, which deposit a light-yellow ochre. At the above locality the springs were seen to issue from beds of sandstone and conglomerate, with travertine containing dicotyledonous leaves.

The section is as follows:—

a. Banks of valley composed of Drift.

Coarse ferruginous sand very moist, with beds of blue- and buff-coloured clay, the whole having rounded boulders irregularly dispersed.

b. 20 feet of coarse and fine sandstone impregnated with lime, also gravel and shingle, and bed of travertine (*c*) with dicotyledonous leaves.

Ancient valley-deposit?—or underlying the Drift?

d. Present river-level with banks, 8 feet high, of silt and fine sand, forming the "points" and densely wooded islands in the channel.

I was unable to determine whether these beds have been formed, like the silt-banks of the river, at a time when it was much larger than at present, or whether they are beds cropping out from beneath the drift. They are quite consolidated, but this may have resulted from the calcareous nature of the matrix.

It will be seen that the observations I have made respecting the distribution of the Tertiaries on the eastern plains are very disjointed and unsatisfactory. As the Cretaceous strata overhanging the Winnipeg group of lakes appear to dip to the west, again to rise to the *Côteau des Prairies*, it is probable that the trough which they thus formed was occupied by Tertiaries of the same age as those that cover the Cretaceous strata on the Upper Missouri; but that, in the immense denudation that has taken place, they have been unable to withstand the erosion so well as the tough clays that underlie them, which had therefore remained as a shoal further out to sea, while along the shore the more yielding strata were being rapidly ground down under the combined action of currents and stranded ice.

Although it is probable that Tertiary basins occur in the plains further west, especially some of the groups that yield lignite, these will be afterwards described along with the Cretaceous strata, as there is an absence of data by which to discriminate them.

CRETACEOUS SYSTEM.

Nearly the whole of the great area of prairie country from the eastern axis to the Rocky Mountains is occupied by Cretaceous strata, which have attained an enormous development throughout the central portion of the North American continent.

The classification of these strata, as they occur in the prairies to the south, has been worked out during the last six years by Messrs. Meek and Hayden with great success, and the results have been published as memoirs in the 'Proceedings of the Academy of Natural Sciences, Philadelphia.' The Reports of the various Pacific Railway exploring expeditions also give details and descriptions of the fossil remains which have been found in this group.

Messrs. Meek and Hayden divide the Cretaceous System of the Upper Missouri into five groups; but my observations were not sufficiently extended to warrant my referring the different Saskatchewan strata to these without much doubt, more especially as I had not the benefit of their valuable reports, which were published while I was engaged in the exploration. In the following vertical section I have therefore adopted a different method of lettering, only indicating the probable equivalents of their section. In the case, however, of one group (E), Mr. Meek has identified the strata from fossils submitted to him by Mr. Hind. The groups in my section do not perhaps truly represent successive periods in time, but rather indicate the different conditions that existed in the geographical areas in which they were deposited.

Vertical section, in descending order, of the Cretaceous System, as developed in British North America.

F. Arenaceous clays and sandstones, with *Scaphites*, *Nautilus*, *Avicula*, and other marine *Mollusca*. No. 5 of Meek and Hayden.	Observed by Hind on South Saskatchewan below the Elbow. Lower part of section at La Roche Percée? At the elbow of Battle River?
E. Indurated olive-coloured shales, with bands and fissures filled with clay-ironstone. *Leda Hindi*, *Ostrea lugubris*, scales of Ctenoid Fishes, Annelide-tubes, and Plant-remains. Also observed by Hind, *Natica*, *Ammonites*, &c. No. 4 of Meek and Hayden.	Forms the high grounds cut through by Long Creek and the Souri River. Also at the Forked Creeks near the Assineboine.
D. Dark-purple and brown laminated clays, with ironstone-septaria, and sometimes crystals of selenite. *Baculites*, *Inoceramus*, *Pholadomya*, *Cardium*, *Exogyra*, *Astarte*, *Cytherea*, *Ammonites*. No. 3 of Meek and Hayden.	Valley of Assineboine at Fort Ellice. Elbow of South Saskatchewan, Eagle Hills, and on North Saskatchewan to Fort Pitt. On north slope of Cyprés Mountain. In the Gulf of Georgia, on Vancouver's Island, at Nanaimo River, Saltspring Island, and at Valdez Inlet, by McKay.
C. Sandstone overlying marly clays, banded with thin seams of ironstone, thin beds of limestone, stiff dark-blue clay, and arenaceous shales. *Ostrea cortex*, *O. vellicata*, *O. anomiæformis*, *Cytherea*, *Mytilus*, *Cardium*, *Venus*, *Natica*, &c. Stems and roots of silicified trees.	Battle River? Hand Hills, Red Deer River. (Not observed on west side of Rocky Mountains.)
B. Great lignite-group *; sandstones coarse and friable, or argillaceous and concretionary, indurated shales, and soft limestones, ironstone-nodules, beds of lignite 3 to 10 feet thick: silicified wood, *Taxites*, and sedge-like stems in the sandstones. No. 1 of Meek and Hayden. Includes the Wealden (?).	Red Deer River, North and South Saskatchewan, Athabasca, and Pembina Rivers, &c. Nanaimo, Vancouver Island, Bellingham Bay, Burrard's Inlet, Gulf of Georgia, &c. The position of this group is not clearly made out to the east of the Rocky Mountains, as the sections at the first and second localities are, so far as is known, contradictory. The beds at Battle River, Edmonton, and Lower Red Deer River may be Upper Cretaceous or even Eocene.
A. Green sandstone and conglomerate at base of lignite-group at Nanaimo, tufaceous sandstone-conglomerate, much altered, and containing *Trigonia Emori*, *Cytherea Leonensis*, *Arca* (2 sp.), *Psammobia*, *Exogyra* (2 sp.), *Ostrea* (2 sp.), *Rostellaria*, *Pecten*, &c. Jurassic?	Fossil Point, Departure Bay, North of Nanaimo in Vancouver Island.

* It is possible that the lignite-bearing group B, which occurs in two lines

Bituminous shales, resting on limestone and covered by friable sandstone. The shale takes fire and burns spontaneously. The limestone contains fossils that are Jurassic (?). [From these shales perhaps come the two species of *Ammonites* described by Hind.]	Described as occurring on the Mackenzie River by Richardson. Similar bituminous shales on the North Saskatchewan and on the Athabasca where it cuts through to outer range of the Rocky Mountains. Containing *Ostrea* and *Cardium*.

[For comparison with the foregoing section I give three sections of the Cretaceous beds and the Tertiaries immediately overlying them, extracted from the Reports of the Mexican Boundary-commission, vol. i. p. 126 *et passim*, where an able digest of their relations is given—prior, however, to the most recent of the researches of Meek and Hayden.

First. *Section of Eastern States. New Jersey.*

VIII. Upper greensand beds (3rd).
VII. Coarse and fine beachsand.

Nos. 4 and 5 of Meek and Hayden.
VI. Middle greensand beds (2nd).
V. Quartzose sand, indurated and concretionary, with oxide of iron.
Exogyra costata, Ostrea larva, Belemnitella, Pecten.
IV. Lower greensand beds (1st), marly clays.
Exogyra costata, Ostrea larva.
Gryphea, Ostrea vesicularis.
III. Dark-coloured clays, greensand in patches.
Ammonites Delawarensis, A. placenta.
A. Conradi, Baculites ovatus, and casts of *Cardium.*

In this position should be Nos. 2 and 3 of Meek & Hayden.

No. 1. of M. & H.
II. Dark clays with *fossil wood.*
I. Fire- and potter's clay, *fossil leaves and wood.*

Second. *Section of Strata on Mexican Frontier.*

Tertiaries of west coast. *Miocene.*

Tertiaries east of the mountains; sandstone, sands, and conglomerates like those of the Mauvaises Terres in Nebrasca.

Calcareous beds with marine Eocene fossils underlying unconformably the preceding strata.

Cretaceous.

1. Argillaceous beds. *Exogyra costata.*
2. Calcareous beds, buff- and lead-coloured, with beds of white limestone. *Gryphea Pitcheri, Cardium multistriatum, Toxaster, Holectypus, Ammonites Texanus, Hippurites, Nerinea, Caprina,* &c.
3. Sandstones of various colours with beds of clay.

Carboniferous.

Third. *Section from the Missouri westward.*

Tertiary indurated clays, sandstones, conglomerate, and limestone, with mammalian and chelonian remains, and fresh-water shells.

Cretaceous. Nos. III. IV. & V. of the New Jersey Section.
5. Arenaceous clays, argillo-calcareous sandstones. 80 feet.
4. Plastic clays, concretionary calcareous sandstone. 250 to 300 feet.

C. & D. of Nicollet. This is the principal fossil-bearing bed of the Upper Missouri.

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separated by a belt of clays like C, may include deposits of two different ages—the one Upper Cretaceous or Eocene, like the beds at La Roche Percée, and the other Cretaceous, in the position assigned to it in the section.

A. & B. of Nicollet.	3. Calcareous marl, *Ostrea congesta*, *Inoceramus problematicus*, scales of Fishes . . . . 100 to 150 feet.
	2. Clay with few fossils . . . . 80 feet.
Nos. I. & II. of New Jersey.	1. Sandstone and clay with fossil wood. . . . . 90 feet.

"The change from III. to IV. is always well marked.

"*Inoceramus problematicus*, which is the same as *I. fragilis*, is the characteristic fossil of Nos. II. and III., and with *Ostrea congesta* ranges to Mexico.

"These latter groups everywhere rest on the sandstone and clay beds (No. I.), which are the 'Jurassic' of M. Marcou.

"With the exception of two species, the Cretaceous fossils of the Mexican frontier are distinct from those of the New Jersey section, and nearly equally so from those of Nebrasca; whereas the latter or Nebrasca section, extending from the Missouri westwards, has many fossils in common with those of New Jersey and Alabama. It is therefore probable that the Mexican beds represent a different epoch in the Cretaceous series from those of the east and north-west. However, from the Mexican frontier no sections were obtained to show whether one or more groups were represented."—Rep. Mex. Boundary-commission, vol. i. p. 126.]

Group F.—In speaking of the Tertiaries, I have mentioned the only places where it is probable that the route of the Expedition touched on the strata of this group—viz. at the height of land of the Qu'appelle River and at La Roche Percée, where the lower sandstones may perhaps be of this age.

Group E.—By reference to the map, it will be seen that the first point where the route of the Expedition passed over Cretaceous strata, was after gaining the great plain of which Pembina Mount forms the eastern limit, at Long River, latitude 49° 8′ N., longitude 98° 35′ W., which is a tributary of Pembina River, flowing northwards. This stream flows through a deep valley in the high plateau stretching back from Pembina Mount, and in its gulleys are exposed sections of group B. It is a compact shale of light greenish-drab colour, not occurring in continuous layers, but as fragments with irregular conchoidal surfaces, which have been produced by the desiccation of what were originally thin layers of clay. Sometimes it has more of a slaty character. Among these beds are hard bands and nodular masses of dark-brown clay-ironstone, and perpendicular fissures are common, which are filled up with splintery iron-shale. Also small coloured tubes traverse the strata perpendicularly in large numbers.

The same strata were observed at Forked Creek, where a deep gulley joins the valley of the Assineboine in latitude 50° 6′ N., and longitude 101° 18′ W., and these two places are both on a line of high hilly ground, which stretches in a north-west direction, no doubt marking the outcrop of the shales. At Long River they dip gently to the south, and are covered by 6 feet of pure white sand, very incoherent; and over this lies the Drift, consisting of light-grey calcareous earth. At Forked Creek they seemed to be strictly horizontal, and were covered by a local drift derived from the subjacent beds. Mr. Hind, who also saw the beds at Forked Creek and other localities, submitted the fossils which he obtained to Messrs. Meek and Hayden; and they have referred them to their second highest group. He gives the following list as named by them*:—

* Rep. Sask. Exploring Expedition, p. 180.

Anomia Flemingii.	Natica obliquata.
Inoceramus Cedarensis.	Avellana concinna.
Leda Hindi.	Ammonites (sp. indet.).

Of those from my collection has been determined the *Leda Hindi*; and, in addition, *Ostrea lugubris*, scales of Ctenoid Fishes, Annelide-tubes and Plant-remains were also found. Traces of these beds were observed to the south of the Qu'appelle River, and also on the North Saskatchewan on the left bank, a considerable distance above the Eagle Hills. Mr. Hind also observed them to form part of the high escarpment of the Duck and Riding Mountains which overhang the lakes, reaching an altitude of 1000 feet; and it was at 500 feet from the summit that he detected these strata.

The group has not been distinguished from the next on the map which accompanies this paper; but, from the more resisting texture of these shales, it is probable that they occupy a larger area of the lower plains that have been subjected to such great denudation than any other group of strata.

Group D.—At Fort Ellice the banks of the Assineboine are 240 feet high, and in general their structure is obscured by vegetation, but at one point a recent slide displayed a partial section of the bank. The upper part consisted of the comminuted fragments of the last-described shale, along with beds of pure sand, and also the more common yellow drift. Close to the water's edge, masses of strata of tenacious calcareous clay were exposed, of a dark-purple colour, but presenting a weathered surface decomposing into a ferruginous earth. Along with these strata were two beds of soft clay-ironstone about 4 feet apart; the lower one half a foot thick and rather compact, the upper one concretionary, forming thick nodulated masses, the surfaces of which show the *cone-in-cone* structure. At this place only a few fragments of the nacreous shell of *Baculites* were found, but sufficient, along with the mineral resemblance, to identify these beds with group D in the vertical section. At the elbow of the South Saskatchewan, where that river cuts through the great prairie-côteau, the boulder-drift is seen to rest on strata of purple clay (fig. 1, p. 395), with nodular masses of ironstone, having veins and cavities filled with calc-spar. These Septaria are in great numbers, and, when broken, are found to include fragments of the following fossils:—

Baculites compressus.	Cardium.
Inoceramus (*I. Crepsii* of Roemer and Conrad).	Exogyra.
	Astarte Texana.
Pholadomya occidentalis (*Morton*).	Cytherea.

The outcrop of these Septaria-clays has a clear relation to the great prairie-ridge which is cut through by the South Saskatchewan at this point, and continued to the north-west by the Eagle and other hills to near Fort Pitt, where it hems in the North Saskatchewan in like manner, the banks having an altitude of 500 feet, and also displaying sections of the strata with the same fossils. At the base of the Eagle Hills, and wherever they prevail, they form lofty and ruinous banks, the strata breaking away in great slices, which slide forward successively. I have counted as many as thirteen such slides on the bank of the river; the oldest, though now close to the water-level, still bearing part of the original prairie-surface, with the same turf that once grew 200 or 300 feet above its present position. The result of this is, that it is seldom that anything can be learnt of the strata which form the full thickness of the river-banks, the more superficial beds being repeated again and again in each slip, so as to give a very exaggerated idea of their development. Above the elbow of the South Saskatchewan the strata are very dark, and contain a large quantity of selenite in radiating crystals. Portions of those soft strata have been formed at this place, by the action of the weather and of the river on their base, into lofty conical mounds, which present a most extraordinary appearance. As no grass has time to grow on them from the constant attrition of their surface, they are perfectly black, and their outline is broken into terraces by the successive lines of ironstone-concretions, which from their hardness retain the soft strata underneath them. At the base of the Cyprés Mountains, where these hills begin to rise from the plains that lie between them and the South Saskatchewan, the sides of the *coulées* are formed of the same Septaria-clays, with fragments of *Inocerami*, and presenting the usual rugged features. This locality would be very favourable for the study of the whole Cretaceous group and the overlying Tertiaries which form the summit of the high lands of the Missouri Côteau, were it not so dangerous on account of the different hostile Indians that move about in strong parties through it. The Expedition only spent a very few days at this interesting place, as it was here that we broke up into parties to explore the Rocky Mountains in 1859. From the few observations I was able to make however, I have been induced to carry the line of these strata from the elbow of the south branch along the *côteau* to the Cyprés Mountains, besides their outcrop to the north-west, along the line of the Eagle Hills to Fort Pitt. In the prairies this and the other groups of the Cretaceous System preserve an unaltered condition, and rarely present other than a most gentle dip; but close to the Rocky Mountains, and also within the plications of the older rocks forming that chain, altered shales, highly charged with iron and resting on sandstones, were observed, which at the time I was inclined to consider to be these Septaria-clays, as the concretions had a very great resemblance to those of this group.

Similar beds with *Inocerami* were also observed at Nanaimo on Vancouver Island, but I shall describe the whole strata at that place together, and for the present confine myself to the development of the Cretaceous System in the Eastern Prairies.

Group C.—A very large proportion of the higher plains to the west of the Eagle Hill Côteau is occupied by the fourth great group of the Cretaceous strata. It is met with forming the banks of the lower part of Red Deer River, near where the Expedition crossed it during the last summer's explorations. From that part it rises to the westward, until, at the Hand Hills, the sandstone which forms its upper member has preserved it as outliers, having abrupt escarpments to the west. By its marked lithological character it was also recognized on Bow River to the south for a considerable distance above the mouth of Belly Biver, and also yet further to the south-west, forming the high broken grounds over which I passed on my journey from the Cyprés Mountains to the Rocky Mountains in August 1859. It was also met with at the elbow of Battle River, and above Fort Pitt, on the North Saskatchewan, where it seems to form the banks of that river for a considerable distance, but is wanting above the Snake Portage, until it reappears again at the Pyramids about 100 miles above Fort Edmonton. Between these points it probably forms the high grounds back from the river, such as the Beaver Hills, Bears' Hill, and the hills round St. Ann's to the west and north of Edmonton. I offer this sketch, however, of its distribution more as a surmise founded on the physical features of the country, than from actual observations of its relations at these various points.

Excepting very obscurely below the Snake Portage on the North Saskatchewan, I cannot say that I anywhere observed the relation of this group to the Baculite-clays of the preceding division. I descended that river on the ice, travelling with dogs, in March 1858, and as the late season compelled me to travel a great deal in the night I missed many points of interest. Its relations to the strata below it were apparently shown on Red Deer River.

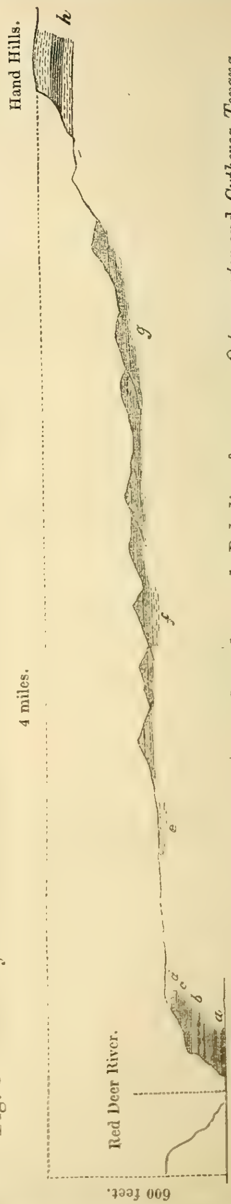
At this place the group is found to form the broken country round the base of the escarpment of the Hand Hills, which probably in their full altitude include several of the members of the Cretaceous System, and therefore merit a more minute description.

These hills form a high mass of table-land a few miles back from Red Deer River, presenting an abrupt escarpment to every quarter but the east, in which direction they slope off gently with the dip of the strata.

Our encampment on June 25th, 1859, was in one of the deep ravines on its western face, 375 feet above the plains below, and 160 feet below the level of the plateau above.

In the upper part of the escarpment facing the S.W., grey coarse sandstones were exposed, which had a considerable dip to the N.E. The bedding of these was hard and distinct, and they were seen to rest upon soft incoherent sandstone underlain by light sandy clays and blue-clay shale (see section, fig. 5). In the clays are enclosed angular masses of black iron-shot sandstone, and also pebbles of quartz and granite. No evidence of the exact position of these strata was obtained; but, although they were somewhat disturbed, I saw no reason to doubt that they are a superior member of the Cretaceous series overlying the beds next to be mentioned, which are of the group C. Fig. 5 (p. 418) gives a sketch of the strata of the hills from the valley of Red Deer River northwards; and it will be seen that there is an interval of several hundred feet between the sandstones and clays and the banded clays of group C, the nature of which was not ascertained. These banded clays, which occupy a narrow tract of country round the Hand Hills, give rise to large white mud-swamps, which we found at the season of our visit to be nearly dry, and presenting a very rough surface from the floundering of the large herds of buffalos in the tough plastic clay bottom as they had been eagerly striving for the last trace of water. These clay beds, which contain a large proportion of calcareous matter and are often "banded" by thin seams of soft ironstone, have a white chalky aspect, and are so easily acted on by the weather that what were originally gulleys soon expand into wide flats bounded by conical hills, with bright surfaces marked regularly at every few inches by the parallel streaks of ironstone, which are often only half an inch thick. From these swampy flats, that serve as reservoirs for the water which descends from the hills in spring, the streams have worn deep ravines which join the valley of Red Deer River. At the commencement of one of these, or near the base of the group C, the "banded clays" were seen to rest on red iron-clay shales in thin beds, underneath which is a bed of rotten limestone of a buff colour, which again rests on a bed of shell-conglomerate, principally composed of fragments of *Ostrea cortex* aggregated into a solid rock with many complete specimens of the same shell. Mr. Etheridge has identified this shell, which is a species described by Conrad in the Mexican Boundary Commission Reports (p. 157). Together with *Ostrea multilirata* it was found at Dry Creek, Mexico; and, in describing them, Conrad says that he knows no species like them in the Cretaceous System, and that probably they belong to strata of still earlier date. However, at another locality, near the Hand Hills, I again found *Ostrea cortex*, and along with it *O. vellicata* and *Cytherea Texana*; and these are undoubted Cretaceous shells of Mexico. From between El Passo and Fontera, which seem to be places within a few miles of each other, the following list of fossils is quoted in the Mexican Boundary Report—*O. velli-*

Fig. 5.—*Section from the Red Deer River to the Hand Hills; the Middle Cretaceous and Lignite Groups.*



a. Great Lignite. *b.* Brown coal. *c.* Silicified wood. *d.* *Paludina*, &c. *e.* *Ostrea cortex* and *Cytherea Texana.*
f. *Ostrea cortex.* *g.* Banded marlites. *h.* Sandstones and dark clays.

cata, *Cytherea Texana*, *Exogyra* (2 sp.), *Trigonia Emori*, *Arca*, and *Nodosaria*,—thus including both fossils found in the neighbourhood of the lignite on Red Deer River, and also some that were found along with that of Vancouver Island.

On Battle River, in latitude 52° 17′, the banded clays were also observed with the same features and with the same fossils. From that river to Red Deer River they appear to form the surface of the country, as every shallow ravine shows slides of the white chalky beds, and the white mud-swamps are very common. At the "elbow" of Battle River, the strata have a slight easterly dip; and in the upper part of the bank were obtained in a concretionary sandstone *Avicula*, *Cardium*, *Cytherea*, and *Baculites compressus*.

A little higher up the river, and towards the base of the bank, *Ostrea cortex* was found, as on Red Deer River. For fifteen miles above this point the valley is cut through these strata; and then the banded clays are seen to form the higher portion of the banks, still with rolled fragments of *Ostrea* at their base in some places, and resting on strata containing silicified wood, which form the lower part of the bank, while in the bottom of the valley the true lignite appears.

Group B.—In my next and lowest group I have (with great hesitation) classed the large deposits of coal or lignite, of the Prairie-country, that are sufficiently compact to be of value as fuel, but which have hitherto been generally classed as of Tertiary age.

However in all the sections which have been given of the Cretaceous System in the United States, it will be observed that the lowest beds are always described as sandstones containing fragments of fossil wood. Further, Dr. Hayden has pointed out that, at the base of his Lowest Cretaceous group fresh-water beds occur, in which the shells are more nearly allied to Tertiary forms, and that the vertebrate remains, of which only a few bones have been obtained, are considered by Dr. Leidy to belong to an equivalent of the Wealden period in Europe. In the same horizon has also been found angiospermous leaves, such as *Quercus*, *Salix*, &c. At the same time he remarks that the fossils from the Judith River beds of the supposed Wealden age cannot be distinguished in many instances from those of the great lignite-basin, which he knows to be Tertiary beyond doubt, mentioning as instances an *Ostrea* and a *Trionyx* that were considered common to the two formations. It may therefore be justly concluded that this question is one of great nicety and doubt, which will only be slowly cleared up as those vast territories become explored. Nevertheless, we are by these observations prepared to consider as possible at least the existence of a coal-bearing formation at the base of the Cretaceous System, even though developed to an extent not hitherto recognized*. In his description of the lignite-formation on the Mackenzie River,

* Since writing the above, I have seen a paper by Dr. Hayden, published in 1857, and before the only other memoir of his that I had access to, in which he suggests that his Lowest Cretaceous group may be only an extension of the lignite-group which extends from the Arctic Ocean, but which, like that group at Judith, may be mixed up with Tertiary strata, also containing lignite.—Proc. Acad. Nat. Sci. May, 1857, p. 116.

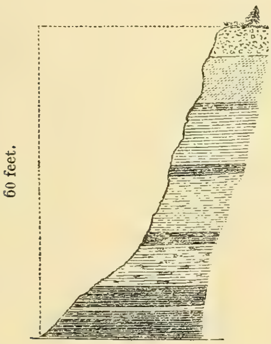
Sir John Richardson refers to strata of a similar nature as occurring at Edmonton on the North Saskatchewan; and, on first arriving at that place in January 1858, I had no difficulty in identifying the beds there with those which he describes. I got not only the same yew-like leaf (*Taxites*) that he figures as characterizing the shales, but also the same general succession of strata, excepting only the beds of shingle and gravel, which he describes in his sections of the Mackenzie River. Before leaving England, Colonel Lefroy furnished me with the following extracts from his notes on Peace River, a point midway between the Mackenzie and Fort Edmonton, which are sufficient to show that the strata are probably continuous throughout this area. He observes that "at the ramparts on Peace River is a vertical cliff of sandstone with broken stratification towards the top," and that "at Dunvegan the river is depressed 600 feet below the general level, and great quantities of crystals of sulphate of lime were collected in the upper strata, while actual coal occurs in the seams about ten miles above the fort on one of the small tributaries." The lignite-formation has also been remarked on Smoking River, a tributary of Peace River; and I have traced it on the Athabasca and McLeod Rivers, and on Pembina River, all to the north of Edmonton; thus proving the range of this formation over a slope rising from 500 to 2300 feet above the sea, and yet preserving on the whole the same characters, and showing no evidence of recent local disturbance beyond the gentle uplift which has effected this inclination.

I shall now describe this formation as it was observed in different parts of the country explored, commencing with the North Saskatchewan. The lowest point on that river where the coal was actually observed, was about two miles below Fort Edmonton, where a thick bed of it was seen dipping gently out of sight below the water-level to the N.E. I have reason to believe, however, that other beds of it occur further down the river for a distance of 50 or 60 miles.

At Fort Edmonton the flanks of the river-valley are from 190 to 250 feet high, and at most places densely wooded. Seven to ten miles back from this valley, on either side, a line of high ground rises from 200 to 300 feet above a willow-covered plain, and consists, as far as I could learn, of the white marly clays of the group D; but the country in this neighbourhood is much obscured by superficial deposits and by small copse-wood. The river-valley has a wide flat bottom through which the river winds in a channel 40 to 60 feet deep, and wherever this present channel sweeps close under the higher valley-banks, sections are displayed, disclosing horizontal strata of arenaceous clays, sometimes passing into clay-sandstone with spherical concretions, but at others into clay-shales. Many of these beds are highly charged with nodules of clay-ironstone, which are filled with comminuted fragments of vegetable matter. The coal occurs in the clay strata, and varies greatly in purity. It is used in the forge at the fort, and is found to answer very well, excepting that it "burns" the iron more than ordinary coal. It ignites with difficulty, but keeps alight for a very long time, and, if left to itself without a draught, smoulders away into an abundant orange-coloured ash. It contains a quantity of water in its composition, as, although generally compact, like fine bituminous coal, when first excavated, it soon splits up into fragments which have dull earthy surfaces. There is a great difference in the quality of this lignite or coal, according to the bed from which it has been procured, and also the distance from the outcrop to which the seam has been worked. There are no sinkings of any sort into any of the seams, the manner of procuring the small supply which is required for use at the fort being for the blacksmith to go down to the river-bank with a pick, and procure a few basketfuls where he can most easily get access to the material.

The fort stands about 100 feet above the water-level, and below it in the bank there are two seams of 18 inches each, but on the opposite side of the river, at a little distance below, there are several seams exposed, the principal of which, close to the water's edge, is 6 feet in thickness; and there is one a little way higher where it is 4 feet, with others less pure (see fig. 6).

Fig. 6.—*Section of the Right Bank of the Saskatchewan River near Fort Edmonton.*



In the middle of the 6-foot seam there occurs a layer, 5 to 8 inches thick, of magnesian steatitic clay, which works up into a lather like soap, and is used by the women at the fort for washing blankets.

A sample from the 6-foot seam has been analysed, at the same time with the Lignite from La Roche Percée (see p. 409): Mr. Tookey's results are as follows:—

Carbon	50·60
Hydrogen	3·24
Nitrogen	0·90
Oxygen	14·41
Sulphur	0·42
Ash	15·93
Water (hygroscopic)	14·50
	100.00

"The colour of the ash in each case was buff. When heated in a close vessel, neither of the lignites yielded a coherent coke, the residue retaining as nearly as possible the shape and bulk of the original particles. The gas which was expelled during the process possessed but feeble illuminating powers. Both samples contain a large percentage of water that can be expelled with a temperature of 100° C. This appears to be a characteristic feature in the composition of lignites."

The gravel- and shingle-deposits are seen to rest on the cut edges of the coal-bearing beds, and are therefore of more recent date. They contain fragments of the nodules derived from the underlying strata, along with pebbles of quartz and other rocks, that must have been derived from elsewhere. Also large fragments of silicified wood are found in the subsoil at Edmonton, the same as that found in the upper part of the lignite-group on Red Deer River, as will be described.

At the bend of the river below the fort, and on the same side, the bank looks as if broken tiles had been strewn over it. This arises from the coal having at one time been completely burnt out, only being represented now by a thin layer of ash, while from the baked clays above and below the red tile-like material has been derived. Amongst these fragments I obtained impressions of the same Yew-like leaf that Sir John Richardson found in the beds at the Mackenzie River under similar circumstances, but along with dicotyledonous leaves, of which I however found no trace.

For ninety miles up to the North Saskatchewan, above Fort Edmonton, the grey arenaceous clays prevail, forming the banks of the river, which are high and precipitous, the valley for that distance making a succession of abrupt bends after every few miles of a straight course, its main direction being to the north.

The secondary banks are also gradually lost, until at length, from the valley narrowing, the river occupies its full width. Above this point, however, the valley suddenly widens and preserves on the whole a straight course from the west, independent of the windings of the river itself, which has a very tortuous course between secondary banks, crossing from side to side of the great valley round heavily timbered flats. Where the river sweeps under the high banks, sections about 200 feet high are exposed of white variegated marls, which are cut in the most regular manner by gulleys into pyramids, with a most artificial appearance as seen from the river, their bright chalky surfaces being thrown into strong relief by the dark-green pines that clothe the ravines. These marls have much the look of those of group C.

Fifteen miles below the mouth of Brazeaus River, which is a large tributary to the North Saskatchewan from the west, we again meet with the lignite-bearing arenaceous strata, and from this point they were traced uninterruptedly to the base of the mountains. The formation now presents very different characters from those at Edmonton, having more the appearance of a shore-deposit. The mineral composition is very varied, and large deposits of sandstone occur, which is fine- or coarse-grained, but never makes any approach to a conglomerate. At the Rocky Mountain House, in latitude 52° 21′ N., longitude 115° 10′ W., where I had the best opportunity of examining this formation, I divided it into three groups, judging from the mineral composition alone; as they were found to pass from one to the other without superposition, just as we might expect to find in a shallow lagoon-deposit.

1st. Coarse-grained sandstone, composed of angular grains of quartz cemented by calcareous matter, present in small quantity. This sandstone forms bold perpendicular cliffs, often 150 feet in height, and hemming in the river on both sides. It resembles the descriptions given of the sandstone of the "ramparts" on the Mackenzie and Peace Rivers; and indeed on all the rivers this formation may be traced by this marked feature as far south as the Missouri at least, as a drawing of the falls on that river (given in Pac. Rail. Rep.) exactly resembles these sandstone cliffs.

The 2nd group consists of beds of green argillaceous sandstone, which, as it weathers easily, always gives rise to sloping banks, from which protrude concretionary masses. These beds are generally horizontal, but sometimes present a rapid dip towards the edges of basins in the last group in which they seem to have been deposited. They are, however, often overlain by the hard-bedded sandstone.

The 3rd group more resembles in its mineral characters than the other two the beds at Edmonton, consisting of alternations of clay-shale and argillaceous sandstone in irregular beds, and including deposits of coal or lignite. The shales, which are often very hard and compact, contain fragments of the Yew-like frond, and also stems of plants like sedges.

Fig. 7 (p. 424) is an attempt to combine the different sections that were observed at the Mountain Fort. The irregularity in the mineral composition is well shown about five miles above that place, where in a very short distance beds of clay and soft green sandstone are suddenly replaced by cliffs of grey and yellow sandstone with heavy bedding*.

* The features of the strata at the Mountain House are very similar to the description given of the Lower Cretaceous groups at Seargent's Bluff on the Missouri by Meek and Hayden, where the following section is described:—

"1. Dark-coloured clay with sandstone seams	6	feet.
2. Light-yellow clay passing into grey sandstone	5	,,
3. Dark clay with fragments of carbonized wood	1½	,,
4. Grey indurated clay or marl with wood	4	,,
5. Dark seam like No. 3.	8	inches.
6. Clay like No. 4.	3	feet.
7. Grey sandstone (carbonized wood)	2	,,
8. Very dark-grey clay, sometimes black, with organic matter in the lower part, and crystals of selenite	10	,,
9. Grey clay, carbonized wood and hard concretions	30	,,
10. Grey sandstone with wood	2	,,
11. Grey clay, with wedge-shaped masses of hard bituminous lignite or coal and round lumps of sulphuret of iron, to the river-level"		

It is mentioned that the beds thin out in many directions, and that some increase to a great thickness in a few hundred yards.

(Mexican Boundary Rep. vol. i. p. 136.)

As developed at the Mountain House, this formation, whatever its exact age, may be described as consisting of sand and clay in varying proportions—great ridges of pure sandstone, including basins in which have been deposited clays and clay-sandstones charged with coal and ironstone in large quantities.

On the Athabasca River, the valley from Fort Assineboine in latitude 54° 50′ up to the outer range of the mountains at Deadman's Rapid, cuts through argillaceous sandstones, with beds of clay and coal of the same kind as those at the Mountain House. The sandstones are in much greater proportion however, and the lignite-beds are more rarely seen, than in the sections along the North Saskatchewan. At Deadman's Rapid these strata are succeeded by grits and clay-shales in regular beds, undisturbed at first, but, on approaching the mountains, found to be implicated in the late upheavals.

On Red Deer River the lignite-formation was observed at various points, the lowest being at the Hand Hills, which have already been alluded to in speaking of the "banded clays." By again referring to fig. 5 (p. 418), it will be seen that a flat plain extends back from the summit of the river-valley towards the base of the hills where the white mud-swamps are situated, but which is cut up by great ravines, which gradually deepen as they approach the river. The river-valley itself is half a mile wide, and 270 feet deep.

At the commencement of one of the ravines, about three miles back from the river, were found the fossils before mentioned (*Ostrea cortex*); and in another, at only a quarter of a mile back from the river-valley, that fossil was again found in the highest part of the bank, along with *Cytherea Texana*, showing that these beds must form the surface of the level flat. At the mouth of the same ravine (Shell Creek), the following sections were observed in the bank of the valley of Red Deer River, the beds being to all appearance horizontal:—

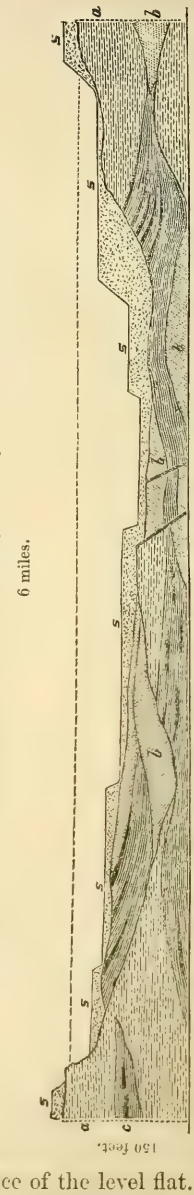


Fig. 7.—*Sections along the Saskatchewan River, at Rocky Mountain House, combined in order to show the variation in the beds and the terraced arrangement of the Superficial Deposits.*

a. Coarse-grained sandstone; with fragments of carbonized wood. *b.* Fine-grained concretionary greensand. *c.* Shales with lignite and ironstone. *s.* Shingle and gravel forming terraces of an ancient valley.

a. Buff, unstratified, earthy clay.—12 feet.

b. Ash-grey and cream-coloured sandy clays in bands with thin seams of clay-ironstone and carbonaceous layers ("Banded clays").

Throughout this bed are angular pebbles of ironstone which look like fragments of septaria.—30 feet.

c. Seam of pure lignite ("cuboidal lignite")—3 feet.

d. "Banded clays" very sandy in some places. In other places the coal has been burnt out and the heat has converted the upper beds of this group into material like broken tiles, which lie scattered over the banks. Probably the ochre-beds observed in some parts of the banks are the layers of ash which represent the lignite-bed when consumed.

f. Brown coal. This bed is about 18 inches thick, and in thin leaves, with a paper-like texture; on it rests—

e. 1 foot of silicified wood, composed of stems and trunks, and roots of large trees. In the bed these are of a deep brown-black colour, but the fragments which lie scattered about weather to a light-cream colour on the surface. One silicified root measured 18 inches in diameter.

g. Sandy clays partially banded, varying from grey to light-cream colour. Crystals of selenite are very common, but no large masses were observed. This group has a very chalky look from a distance. It is probably 100 feet thick, but the base of the section was not observed.

Although these beds are very variable, passing horizontally into different varieties of shales, banded clays, and sandstones, still there seemed to be a definite inclination to the N.E., so that in ascending the river deeper beds were exposed.

A few miles above Shell Creek the lower part of the banks are to a great extent composed of a bed highly charged with ironstone nodules, which have very irregular shapes, unlike the nodules in the other parts of the strata. The profusion of these strewn on the slopes of the valley reminded me of the heaps of roasted ironstone scattered in the neighbourhood of iron-furnaces. A little way further on, where a creek joins the valley, thick beds of coal appear at the base of the section. The lowest bed is 4 to 5 feet thick, and very compact and pure. It is included in the same gritty sandy clay that everywhere forms the matrix of the coal.

The iron-shales immediately overlie these beds, and these are again overlain by the "banded clays" that form the base of the section lower down. By following up Coal Creek for a few hundred yards to where the banks attained a height of 250 feet above the burnt lignite-seam, I found in a hard sandy limestone-bed the following fossils:—

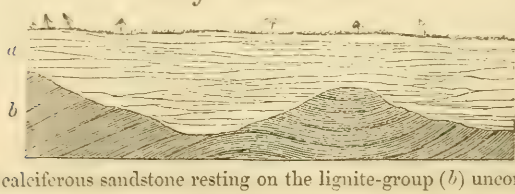
Ostrea anomiæformis.	Crassatella.
Mytilus (2 species).	Venus.
Cardium multistriatum.	Rostellaria.
Paludina.	

No break was observed in the beds, and the succession of the strata from the lignite upwards was such as might be expected in a gradual passage from freshwater to marine deposits. I did not, however, remark the layer of silicified wood or brown coal that I expected to occur above the "banded clays" that overlie the lignite.

On Battle River similar beds were observed in lat. 52° 28′ N. long. 111° 29′ W., having the same order. The high part of the section was composed of the "banded clays" along with concretionary masses of sandy limestone, containing *Ostrea*, *Avicula*, and other shells. Over the "banded clays" is the layer of silicified wood, while at the base of the section and under the water of the river the beds of lignite crop out.

For sixty miles above the Hand Hills I had no opportunity of examining the banks of Red Deer River, but at the mouth of Bull Creek the strata were found to present much the same appearance as at that place; the higher banks consisting of the "banded clays," while along the river are exposed the beds of lignite overlain by the silicified wood. Beneath the lignite, and what must be the lowest bed of the section at this place, occurs a hard grey sandstone with large concretions, that contain a slight admixture of lime, and in these I obtained several leaves of deciduous dicotyledonous trees. The exact spot where these were obtained is just below the mouth of Deadman's Creek. A little above this place the coal forms beds of great thickness, one group of seams measuring 20 feet in thickness, of which 12 feet consist of pure compact coal, and the remainder of carbonaceous clays. At one point the seam was on fire, the bed exposed in a cliff of about 300 yards in length being at many places in a dull glow, the constant sliding of the bank continuing to supply a fresh surface to the atmosphere. For miles around the air is loaded by a heavy sulphurous and limey smell, and the Indians say that for as long as they can remember the fire at this place has never been extinguished summer or winter. For ten miles above this place the coal-beds were traced as we ascended Red Deer River. They are then succeeded by cliffs of sandstone apparently formed by beds overlying the coal-group, but the dip is very slight. The Nick Hills where this sandstone forms a high ridge run to the north-west, and above this point the banks of the river are composed of finely laminated marly clays, often containing concretionary masses of limestone filled with freshwater shells, such as *Paludina*, *Planorbis*, &c.

Fig. 8.—*Section on the Saskatchewan River*, 20 *miles above Rocky Mountain House.*

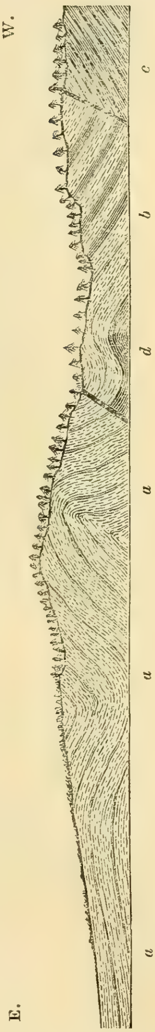


a. Buff calciferous sandstone resting on the lignite-group (*b*) unconformably.

These marly clays overlie the sandstone of the Nick Hills, and seem to occupy a great basin, through which the river flows from above the forks of Medicine River. Traces of a similar deposit of much more recent date than the lignite-group on which it rests, were noticed on the Athabasca River and also on the North Saskatchewan, as shown in fig. 8.

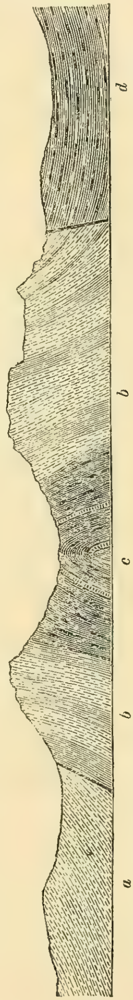
Above that point there appear chocolate-coloured shales with beds of sandstone; and on Little Red Deer River a section (fig. 9) was ob-

Fig. 9.—*Section of the Exterior Range of the Rocky Mountains, on Little Red Deer River.* Length 7 miles; height 600 feet.



a. Heavy-bedded clay-sandstones, with streaks of carbon, becoming disturbed and altered.
b. Sharply bedded sandstones and carbonaceous shales, with thin seams of coal.
c. Septaria-clays.
d. Chocolate-coloured arenaceous shales.

Fig. 10.—*Section along Dead-man River, near the Old Bow Fort.*



a. Concretionary clay-sandstone.
b. Sandstones and shales.
c. Black carbonaceous shales, with coal in thin streaks, and ironstone.
d. Septaria-clays.

served, in which the sandstone beds become disturbed and harder, presenting beautiful flexures and exposing at the base the same shales.

Relations of the Cretaceous Series on the West.—On Weepaioos Creek, a tributary to Deadman's River, and within fifteen miles of the Old Bow Fort, thin disturbed beds are very distinctly exposed, as in fig. 10, and must include an enormous thickness of strata. Although in the absence of fossils I cannot speak positively, yet I believe that these sections include Carboniferous strata, which are represented by the lower grits and shales, which contain coal in thin streaks with plant-impressions. From some of the higher beds at the Bow Fort, a small *Cardium* was procured. Also on the North Saskatchewan, over the grits and shales of probably Carboniferous age, there came beds of pink quartzose grit with dark shales, on which rested a great thickness of black aluminous shale containing a small *Ostrea* in great abundance. Also on the west shore of Lac à Bruler, where the Athabasca River leaves the mountains, the same strata were observed resting high up on the flanks of a mountain of Carboniferous Limestone.

At many other points in the mountains throughout the eastern ranges, patches of shales occur, highly ferruginous and along with grits and heavy-bedded sandstones of various tints, and having apparently a superior position to the rocks of Carboniferous age, of which the greater mass of that portion of the mountains is composed. In the sections of the various mountain-ranges, the beds which I consider to belong to this group I have lettered *a*, and, as they are of great thickness, it is probable that they represent some of the strata that are found undisturbed in the prairies. In the exterior range of mountains on the North Saskatchewan, masses of thick-bedded encrinital limestone rise to the height of 1500 feet with a heavy dip to the west; while the pink grits and aluminous shales dip away from them in every direction, just as if they had been masses of intrusive rock thrust up from below,—thus showing the want of conformity between these limestones and the strata that I consider to intervene between them and the Cretaceous.

Cretaceous Strata of Vancouver Island and the Gulf of Georgia.—The map No. V*. is from the Admiralty-chart of the straits between the south end of Vancouver Island and the mainland, but extended northwards so as to include the portion of the coal-mines. On it I have sketched-in the probable range of the different formations, but in a very imperfect manner, as my own observations were only the result of a trip made in a canoe with four Indians for seventy miles up the coast to Nanaimo. At Nanaimo coal has been worked by the Hudson Bay Company since 1854, and the total export up to January 2nd, 1860, has been about 12,000 tons. Through the kindness of Mr. Nichol, the gentleman in charge of the works, and of Mr. Pearce, of the Land-office, I am able to show a map of the neighbourhood, in which I have inserted my own observations of the Geology (Plate XIII.). At the time of my visit there were three

* It was not thought necessary to publish this map.

pits in operation, giving employment to thirty miners and a number of labourers. The former are principally Scotch and Staffordshire men that have been brought out to the country at the Hudson Bay Company's expense, but the greater number of the labourers are Indians, small tribes of whom come and settle at the mines and work for a short time until they tire of the uncongenial life, when they leave to make room for another band. The irregular supply of labour from this cause adds greatly to the uncertainty and expense of the workings. When working in the best seams at Nanaimo, a miner can put out $2\frac{1}{2}$ tons per day. The shipment from Nanaimo in the month of January 1860 was 2000 tons, the trade having at that time been suddenly extended by the demand consequent upon the establishment of gas-works at Portland, Oregon, and several other places. This demand was supplied from a large stock that was lying on hand at the time, but which, from having been exposed to the action of the weather for many years, was of very inferior quality. In spite of this, however, I understand that the market has continued steady throughout last year, and that the coal has been much used in California for making gas instead of that brought from the Eastern States as heretofore. Coal from the same description of strata has been also worked to some extent on the opposite side of the Gulf of Georgia at Bellingham Bay, and also at Coose Bay in Washington Territory. Although it has been found in many other localities along the coast, as I shall mention after describing the formation, these are the only places where it has been worked to any extent. The whole formation associated with the lignite- or coal-beds is very extensively developed along the Pacific coast, and has generally been considered to be of Tertiary age, excepting from the first accounts sent home, which, as there were no fossils, induced geologists to consider them as Carboniferous. Some fossils transmitted to the Jermyn Street Museum many years ago were first rightly recognized by the late Professor E. Forbes as being Cretaceous; but the localities were undescribed, and, in the absence of sections, it was impossible to deduce anything from them regarding the age of the coal-beds.

The observations which I have now to offer respecting these strata will, I believe, put their age beyond doubt as Cretaceous; but rightly to understand the value to be attached to them requires me to give first a sketch of the physical features of the district.

The southern part of Vancouver Island, where the town of Victoria is built, is composed of metamorphic rocks, with occasional beds of crystalline limestone. This district and also the central portion of the island, as may be expected from the formation, is everywhere hilly and even mountainous, with only limited patches of fertile soil in the valleys. However, the scanty soil on the rocky hills supports a fine growth of timber, so that they are almost invariably wooded to their summits. In the immediate neighbourhood of Victoria there is nevertheless a good deal of fine open land dotted with small oak-trees. On passing to the north through the Canal de Haro, the islands of the archipelago between Vancouver Island and the mainland are seen to be composed of strata of sandstone and conglomerate, which form lofty cliffs overhanging intricate but beautiful inlets. The junction between these two formations was not observed, but I think it is south of San Juan Island, thence crossing to Vancouver Island by Sannich Point, and northwards a little way back from the coast, leaving a narrow strip of fine land*.

These sandstone and conglomerate strata have a uniform strike from N.N.W. to S.S.E., and, in passing along the shore of Saturna Island, they were observed to form several well-marked synclinal troughs, and on passing through the Plumper Pass to dip gently to the N.E. under the waters of the Gulf of Georgia. The nature of the beds was not ascertained beyond the general fact that they are thick-bedded sandstones and conglomerates, and sometimes strata of clay-shale. The sandstones are much acted on by the weather, and at the water-line the sea has generally worn in them caves and hollows. The conglomerates form the highest beds of the series, and are of immense thickness.

After passing the Plumper Pass, in proceeding north through Trincomalee Channel, Galiano Island to the west presents cliffs, about 800 feet high, of the sandstone and conglomerate, with a gentle dip to the east; and sometimes spits or low promontories of the strata run parallel with the coast, enclosing narrow bays. The west side of the channel on Salt Spring Island is a low shelving coast heavily timbered to the water's edge, and exposing outcrops of grey and blue clay-shales, which dip to the east. The portion of this island which is occupied by these shales is the finest land for settlement I have seen on the coast; but the southern part is mountainous, rising to the height of 2300 feet. It is on the north part of Salt Spring Island that the saline springs are situated from which it gets its name. They seem to escape from the shales, and occur in spots clear from timber and covered with green moist vegetation abounding in saliferous plants. Round the orifices from which the brine escapes, there have formed conical mounds of granular calcareous sinter stained with

* I am informed by Lieut. Roche, R.N., that, when stationed on that coast, he discovered a copper-lode, and detected it on Moresby Island and various points in a line running S.E. by E., as indicated on the map. I have not myself seen the samples he brought away, but copper in the metallic state is known to exist in quantities further north, and I have a specimen of the sulphide of copper which was said to have been found by the Indians on the mainland. There is no doubt that a careful examination of Vancouver Island and the adjoining mainland for metallic veins would yield valuable results. Since my return to England I have heard that the same silver-ore that is found at Washoe, and that raised such a furor in San Francisco a year ago, has also been found on the mountains of Fraser River. The Cascade range of mountains may be looked on as the continuation of the Sierra Nevada of California, and the marked change in the nature of the coast-line north of Vancouver Island shows where the chain begins to dip down to the sea-level; so that what were formerly mountain-valleys are converted into inlets and straits. This is a most important physical feature, and the great facilities for access to the mineral wealth of the country which it affords will exert a powerful influence on the destinies of British Columbia, although at present, in the absence of roads, its iron-bound coast and want of rich flat country are erroneously considered as a bar to its development. Sooner or later it will be seen how wonderfully this new colony is adapted by nature for mining, fisheries, and commerce.

iron; but in summer there is said to be an abundant deposit of pure white salt.

North of Salt Spring Island the strata preserve the same strike and general appearance all the way to Nanaimo, the island forming long spits of sandstone and conglomerate with precipitous shores to the west. Just below the "rapids" the shales were again noticed, resting on the sandstone, and both dipping to the west. At very low tide a thick seam of lignite is exposed at this point and on the island opposite, and to the east I found a thin seam in the sandstones. At Nanaimo the sandstone country occupies a broader belt along the shore of Vancouver Island than further to the south, but immediately to the north the strike changes to nearly east and west on Newcastle Island; and on Fossil Point the lowest beds were seen to rest on igneous rocks, which continued to occupy the coast for the few miles I went further to the north. At the head of the Gulf of Georgia, the sandstones again form the islands that crowd the narrow channel that separates Vancouver Island from the mainland, and also a great extent of both shores. From Comux and Valdez Inlet, which are situated in this locality, some of the fossils which I have were procured by Mr. McKay, of the Hudson Bay Company. Also at the extreme north end of the island, at Fort Rupert, Mr. Lord, of the Boundary-commission, observed the sandstones and thick beds of lignite dipping out to sea.

At many points along the eastern shore of the Gulf of Georgia, these strata have been detected with the associated lignite-beds. North of Howe's Sound the mountains closely hug the sea-coast, but south of that they retire along the north shore of Burrard's Inlet to the south-east, so as to be sixty miles inland where the boundary-line meets them; thus leaving a very heavily timbered track, which forms the only level country in British Columbia west of the Cascade Range. Most of this district is covered by shingle-terraces and other superficial deposits which obscure the underlying strata, but from Burrard's Inlet, eight miles north of the entrance to Fraser River, coal and sandstones containing fossil leaves have been sent home by H. M. S. "Plumper." Also on Fraser River near Fort Langley, and on its tributary Pitt River, the coal has been observed, and then again at Bellingham Bay, south of the boundary-line; so that it is probable that these strata underlie the greater part of this region.

Details of the Strata at Nanaimo.—In the section, fig. 3, Plate XIII., I have represented the whole beds observed at Nanaimo in their probable order, but I did not see any one section giving the complete sequence expressed in it. Starting from Fossil Point, north of Departure Bay, we have the high promontory formed of trap, resting on which are beds of greenstone-conglomerate, consisting of spherical masses of greenstone, cemented by a felspathic matrix. Over this is a tufaceous bed (with imperfectly formed crystals), 5 to 6 feet in thickness, partly fused and often pierced by the trap from below. Then follows a very tough green sandstone quite filled with shells, for many of the specimens of which I am indebted to Mr. McKay.

The following is the list as determined by Mr. Etheridge:—

Trigonia Emori.
Trigonia (sp.).
Cytherea Leonensis. (This is the most common shell.)
Arca (3 species).
Exogyra (2 species).
Ostrea (2 species, one of which is of great size).
Rostellaria.
Psammobia (?) sp.
Pecten *.

In speaking of the beds on Red Deer River, I referred to the fossils found at this place as showing the existence of forms which are in Mexico associated with those of the Saskatchewan, and in every case found in the proximity of the lignite-beds. Thus in particular we have *Cytherea Texana*, common to the Saskatchewan and Mexico, and *Trigonia Emori*, common to Mexico and the Pacific coast. This, owing to the very imperfect state of our knowledge and the limited extent of the collections, is probably to be considered as merely an indication of the agreement that may yet be established. The green sandstone beds at the base of the series which contain the lignite seem to have been deposited originally on the surface of the igneous rock, which was probably submarine, so that its surface, chilled by the water, easily broke up into the masses that compose the conglomerate-like breccia, the cement of which has been derived from the tufas that were deposited on its surface. On the shoal thus formed the greensand beds had been deposited, enclosing the molluscous remains. The whole has since been repeatedly disturbed, and some of the lower beds have undergone partial fusion by more recent outbursts.

The sandstone is sometimes quite horizontal, but at others quite vertical for a little way, and is only found as patches all round the promontory and north side of Departure Bay.

Three hundred yards from the shore in the channel that passes between Newcastle Island and the Fossil Point, is a row of islands composed of very fine conglomerate that might be termed "gravel-stone," in beds that dip S.S.E. at 15°. These beds contain small fragments of carbonized wood.

A quarter of a mile further on, in the direction of the dip on the north end of Newcastle Island, there are high cliffs of sandstone, which preserve the same direction. They seem to be rather more disturbed than the strata that form the islands in the channel, but this appearance is exaggerated by the great amount of false bedding. The strata of sandstone continue to preserve the same direction of dip all along the coast of Newcastle Island, but gradually becoming more horizontal towards the southern extremity. On the west side of the Island at Exit Channel occur the seams of coal, the lowest of which has been worked to a considerable extent, while the existence of the other has only been found by boring. The outcrop of these two seams has been ascertained on the east shore of the island, where

* It is probably from this place that the fossils were procured to which Meek and Hayden refer in a notice of the coal of the Pacific coast, contained in the Pacific Rail. Rep. vol. vi., where they say that among the fossils from Vancouver Island a number occur in a green sandstone matrix, which have a strong Jurassic aspect

they have the same characters and relative position, thus showing that they are continuous to that extent. The lowest bed of coal is called the "Newcastle seam," and is worked by levels driven into the outcrop as it rises with the high bank from the shore. The coal or lignite is 6 feet thick, with a floor of sandstone, and a roof of a very tough conglomerate of very small pebbles. The strata have a dip of 20°, so that the method employed succeeds well for taking out small quantities.

This mine was not being worked when I visited it, but there were large heaps of the coal, waiting for a market, that had been lying there for some years, so that I could judge the effect of the weather on it with great facility. The surface was turned to a rusty brown, and the masses showed a tendency to break up with a slaty fracture—otherwise the exposure had worked but little change.

Along the shore of the island to the south, the strata of argillaceous sandstone are seen to dip steadily in the same direction with less and less inclination, until at the southern extremity they are almost horizontal. On Douglas Island there is said to be another seam of coal, from the shales associated with which the fossil leaves are generally procured. I had not an opportunity of visiting it, however. On the coast at Nanaimo Harbour the strike of the strata is quite different, but yet they preserve the same character and sequence, Exit Channel seeming to mark a great fault. The little peninsula on which the Hudson Bay Company's establishment stands, and where the coal was first discovered, is also another dislocated portion of the strata, as may be seen by reference to the map.

At Nanaimo, as on Newcastle Island, there are two seams, the "Newcastle" and the "Douglas,"—the first of which is everywhere about 6 feet in thickness, with sometimes a floor of fire-clay, but more generally of sandstone, and the roof consisting of the fine conglomerate bed, about 60 feet thick, on which rests the Douglas seam with an average thickness of from $3\frac{1}{2}$ to 4 feet. The roof of this seam is sometimes of iron-clay-shale, but more often of the same tough conglomerate that it rests upon. On Chase River, $1\frac{1}{4}$ mile to the south, the outcrop of a seam has been discovered and worked to a small extent, which they consider to be the "Newcastle seam;" and as it occurs right in the line of strike, and as they have ascertained the outcrop at several points, it is probable that the beds of coal are continuous.

In the mines they have met several "stone-faults" or "swells," where the floor rises up and throws the coal-seam out for several fathoms. It is generally represented, however, by a carbonaceous parting. These faults are a source of great expense in the working, as the conglomerate to be pierced is exceedingly tough and compact, so that the blast only brings it away in small pieces.

In proceeding along the coast towards the mouth of Nanaimo River, the strata consist of argillaceous sandstones with a similar character to those of the southern part of Newcastle Island, and preserving a steady though gentle dip to the E. by S. A short way above the entrance to the river, in the sandstones, there is a thin seam of coal, the position of which was pointed out to me by Mr. Nichol, as the river was too high to allow us to see it. Continuing to ascend the river, which is of small size, we found low exposures of the sandstone still with the dip to the E.; and at Fossil Bank, three or four miles from the mouth, they are overlain conformably by dark-purple clays filled with septaria, which yield Cretaceous fossils. The dip of the beds is 10° to the E. by N., and the clay strata were clearly seen to rest on the hard-bedded sandstones.

I found *Inoceramus*, *Baculites*, and some other fossils, of which other specimens are also among those obtained by Mr. Bauerman at this place. I was told at Nanaimo that *Ammonites* have frequently been found there of large size, and from Mr. McKay I got a number of fossils, some of which he obtained at this locality; but others having the same appearance, and also contained in septaria, he procured from Comux and Valdez Inlet at the head of the Gulf of Georgia; but these two sets of specimens had been unfortunately mixed together. For a couple of miles the Nanaimo River flows through these clay strata, and then turns again from the S.W., and in ascending the sandstone strata were again found to recur as in the lower part of the river, but with a more rapid dip. At the "Cañon" these sandstones form precipices about 100 feet in height, bounding a narrow gorge 600 yards long, through which the river flows. The beds dip at 15° to the E.N.E., and are very like those of Newcastle Island.

From under these sandstones, in ascending the river, hard beds of the gravel-conglomerate cropped out with great regularity, separated by soft beds of red and greenish clay. These probably correspond to the group with the coal at Nanaimo, but I failed in finding any proof of it beyond fragments of carbonized wood. The strata from Fossil Bank up to the river, as far as I went, are shown in section No. 3, Pl. XIII.

The total thickness of the beds from the coal to the clays at Fossil Bank I estimated at 600 to 700 feet, but I had no opportunity of making any exact measurement. Between Nanaimo River and the coast, there is a tract of very fine country, and it is probably occupied by the Septaria-clays, which, as I mentioned before, were seen a little south of the rapid.

The following is the list of fossils from the Septaria-clays, which includes those specimens obtained by McKay from Valdez Inlet:—*Inoceramus* (?) (this is the *I. Crepsii* of Conrad and Roemer), *I. Texanus*, *I. Nebracensis*, *I. unduloplicatus*, *I. confertim-annulatus*, *I. mytiloides*, *Baculites compressus* and two other species, *Ammonites geniculatus* and three other species.

It is thus evident that the group of strata with the lignite-seams towards their base must be of Cretaceous age; but as yet it would be premature to infer the exact position which they hold with reference to the rest of that system. The great beds of conglomerate which form the long narrow islands along the west of the Gulf of Georgia must, I think, overlie all these strata.

From the sandy shales associated with the lignite, I forward fragments of Yew-like fronds, just the same as those I got in the shales. At the Rocky Mountain House, and in the collection sent home by H.M.S. "Plumper," all the specimens from Nanaimo are of this plant. Those from Burrard's Inlet are in a different stone, are reticulate leaves, and were also found along with beds of coal; but there seem to be no specimens of the Yew frond from that locality*.

From Nanaimo Mr. Bauerman has also sent home a plant that looks much like a portion of a monocotyledonous leaf.

At Bellingham Bay, sections taken by Mr. Pemberton show that the lignite occurs in a large quantity at that place. Lieut. Trowbridge in describing the strata there says, they are 2000 feet thick, and include, in all, 110 feet of the lignite-coal. His sections are probably, however, all of the same group of strata, taken at different points in the strike, which gives rise to this apparently enormous thickness.

The analysis of the coal from Bellingham Bay, which is generally considered inferior to that of Nanaimo, is given in the Pac. Rail. Report, vol. vi. p. 65, as follows:—

Carbon	47·63
Bitumen	50·22
Ash	2·15
	100·00

This coal has been sold in San Francisco market at from \$18 to \$22 per ton (75*s*. to 91*s*. 6*d*. sterling).

Lignite-coal has also been worked for the same market from Coose Bay, and has the following composition:—

Carbon	46·54
Gaseous matter	50·27
Ash	3·19
	100·00

Conrad states that shells from this locality are of Miocene age.

At Benicia, above San Francisco, coal also occurs, and was wrought for some time, but the dip was too steep.

In Newbury's Report on the geology of this part of California, I have not seen any notice of where this Benicia lignite occurs in his sections; but between Benicia and the sea he describes 3000 feet of strata, the lowest beds being of sandstone and shales resting on, and penetrated by, serpentine and trap (the same which are so highly charged with ores of copper and mercury further to the south). These are followed by green and brown shales, coarse soft sandstone, fine sandstone and shales, with *Pecten*, *Natica*, *Mactra*, and *Tellina*, and these by conglomerates and tufas, the whole lying at an angle of 30°. Towards Benicia are thin-bedded clays with Sharks' teeth. Up Feather River, a tributary of the Sacramento River, at Chico Creek,

* Dr. Hooker has specimens from Disco Island, in the arctic regions, where a Yew frond and angiospermous leaves are associated in the same hand-specimen.

a calciferous sandstone is described, containing *Nucula, Mactra,* and other Tertiary forms; but from the same place are *Baculites, Inocerami,* and *Ammonites,* which Meek considers as proving the existence of Upper Cretaceous strata at that place. So that it is probable that there are strata of both ages, but included in the same disturbances; and it is not unlikely that the section from Benicia to the sea may also include Cretaceous strata*.

The existence of coal or lignite on the Pacific coast, of quality fit for the purposes of raising steam, is of great commercial importance, and that obtained from Nanaimo is as yet admitted to be the best in the market. If these beds are therefore discovered to be persistent, so that they can be worked to advantage on a large scale, there is little doubt that this coal, even though it be an imperfect substitute for the finer coal to which we are accustomed in this country, will form a valuable source of wealth to the new British colony. Already it is extensively used by the British navy on that station, and it was found to require only a slight modification in the method of feeding the fires to make it highly effective as a steam-generator.

As beds of coal of similar quality exist in the Islands of Japan and Formosa, we should thus have the supply of fuel at the extremities of the line of the great sea-voyage, if the route from England by the Canadas, Saskatchewan, and British Columbia to China and the East were adopted—a natural fitness not to be overlooked in considering such a scheme.

PALÆOZOIC ROCKS OF THE EASTERN AXIS.

The general structural features of the country travelled over on the canoe-route, so far as they can be learned from a single line of traverse, have already been well described by Mr. Keating, Sir John Richardson, Dr. Bigsby, and others; but, from the complicated relations of the rocks of which it is composed, no detailed observations can be of any value until they are extended in every direction by means of a combined topographical and geological survey.

The whole of this district is occupied by a primitive axis—the "intermediate primitive belt" of Sir J. Richardson—which is composed of gneiss, mica-schist, crystalline limestones, and other metamorphic rocks, with intrusions of granite, probably of very different ages, the whole formation being the Laurentian series of Logan, corresponding, it is thought, to the fundamental gneiss recently described by Sir R. Murchison as underlying the most ancient strata in Scotland.

From observations made in the course of our journey, it appears that there are two distinct directions of strata in the rock which compose this axis, marking it into two districts, one from Lake Superior to Rainy Lake, the other from Lake of the Woods to Lake Winnipeg. Not only the general strike of the altered and upheaved rocks

* On the Colerado River the Texas lignite or coal, in beds 4 feet thick, has been observed in strata under those with Eocene fossils, and on a tributary of the Del Norte, beds, 3 to 4 feet thick, occur of good working quality, in true Cretaceous strata. (Pac. Rail. Rep. vol. vi.)

in these two districts, but also the direction in which the water-courses affect the principal descents, and the manner in which the lakes in each of them are arranged, all indicate a different direction of the elevating and disturbing force; in other words, two different axes of dislocation.

These seem to converge towards the south, including an angle of about 25°; the eastern one being directed from the north-east to south-west, while the western one lies much more nearly north and south. In each of these there is a great central district where nothing but rounded bosses of granite are seen occurring as ridges and islands, which rise little above the level of the flooded country in which they occur. On either side of these two granitic districts metamorphic rocks are ranged with great irregularity as regards their order and dip, but still, on the whole, preserving their direction very consistently with the bearing of the axes to which they respectively belong. There are besides many minor outbursts of granite occurring as dykes and intrusions, but they do not seem to interfere with the above-mentioned general bearings of the country.

From this cause, in crossing the district between Lake Superior and Rainy Lake, the summit-level is reached by an abrupt and rapid ascent in a direction at nearly right angles to the main eastern axis. Then follows a long traverse, almost along the summit of that axis, and then an abrupt but comparatively short descent to Rainy Lake, again at right angles to the axis.

The first great step in the ascent from the east is made at the Kakabica Falls, where, from a succession of faults which mark the commencement of the more highly metamorphosed rocks, a sudden elevation is effected, the summit-level of which is 179 feet above Lake Superior at Fort William.

About one mile below the fall a fine section is exposed in the form of a cliff 130 feet high, crossing the country from north-east to south-west, consisting of a dark argillaceous schist in thin fissile beds, from 1 to 2 inches in thickness, very much jointed, and having many small veins of quartz, and sometimes calc-spar, included both in the lines of bedding and in the joints. These beds are quite horizontal, and through their whole thickness the river has cut its way back to the present position of the fall in a manner similar to that in which the river-bed below the Niagara Falls has been formed.

They are supposed to belong to the Huronian series, a system which is largely developed on the shores of Lakes Superior and Huron, resting unconformably upon the Laurentian series, and having, according to Sir W. Logan, a thickness of 12,000 feet. This large system, that has not as yet yielded any fossils, and always underlies the Silurian, has been considered to represent the Cambrian.

On the River Kaministoquoiah above the fall at Friar's Portage the strata have an almost vertical position; and a little further on, at Lower Island Portage, are found to be dipping at an angle of 40° to south-south-east, and to be changed in character, having mica developed in them, and also a great abundance of quartz-veins. Immediately afterwards, in the course of the ascent, true granite occurs, and after several alterations schistose flags reappear at Upper Island Portage, but now dipping at a high angle to the north-west.

From the falls to the Dog Lake the ascent of the river pursues a northerly course, crossing the beds obliquely by a succession of minor falls, giving rise to scenery of unequalled beauty. At the Dog Portage another sudden rise takes place in the water-level; for the rocky high grounds which, for a long way below, have been skirting the river at some distance, forming, as it were, the limits of a wide valley, here converge and form a granitic barrier across the river, the summit of which is about 719 feet above Lake Superior, and 440 feet above the river at the lower end of the portage, but only 140 feet above the lake-level at the upper end, thus making a rise in the water-level of 297 feet in the short distance of two and a half miles. As the portage-road passes right over the top of this hill and leads to a point in the lake far from the exit of the river, the nature of the rock at the falls which produce this sudden change in level could not be examined, but the mass of the hills seems to be granite. Although this is not the highest point of land over which we passed during the route, still it is probable that this hill is as high as any portion of the rocky axis of the country; as those along the lake are inferior to it in elevation, while the ascent which is made after leaving the upper end of Dog Lake is through a swampy country covered with drift. In fact, after leaving Dog Lake, until a considerable descent has been made to the west, no rock is exposed, the whole summit-level being covered with a thick deposit of drift.

From the Lake of the Thousand Isles, where the rocky flooring of the country is again uncovered, until Sturgeon Lake is reached, the descent is very slight, and the route follows a chain of small lakes, which are in most cases detached from one another, being separated by rocky barriers over which the canoes and cargoes are carried.

In many cases the lakes are at exactly the same level at each end of the portage, and the greatest difference between the two ends of any of these portages is only about 35 feet, so that the total descent in this part of the route cannot amount to very much. This chain of lakes may, in fact, be considered as occupying a line parallel with the summit of the watershed, and the country in which they lie is almost wholly composed of granite, occurring in broad round eminences, nowhere rising to 100 feet above the level of this half-drowned country. It is probable that this granitic belt is expanded considerably where the old portage-route crosses it, and that the whole chain of lakes between Lake Rasiganagah and Sturgeon Lake lies within it. It is this belt which will form the great obstacle to the formation of any kind of road across this watershed.

From Sturgeon Lake to Bad River there is a considerable descent to the south, which forms the only exception to the general north-westerly descent of the waters to Rainy Lake.

From the Lake of the Cross to Lake Namucan the descent is rapid, and the river-channel crosses the strata of gneiss and bedded greenstones at right angles, following the direction of the dip.

Rainy Lake has its length agreeing with the strike of the strata, which is here more nearly east and west than before.

Between Rainy Lake and the Lake of the Woods the superficial deposits again cover all rocks from view, and when the north end of the latter lake is reached and they are again exposed, their general strike is now changed to almost north and south, agreeing with the greater axis of the lake, just as Rainy Lake agrees with the strike of the eastern district. The descent from the Lake of the Woods to Lake Winnipeg is by successive groups of falls, between which the river forms lake-like expansions, which lie generally at right angles to its main course.

The first part of the River Winnipeg flows across vertical strata, and then enters a granitic district very similar to that passed through between the Lake of the Thousand Isles and Sturgeon Lake.

The strike of the rocks in this region is generally a little to the east of north, and the nature of the strata is very similar to that of the country east of Rainy Lake, but less disturbed by dykes.

No trace was observed of the existence of the schistose rocks on the west flank of the axis, the gneissose rocks continuing for the whole way to Lake Winnipeg.

Silurian Rocks.—Mr. Hind, who had favourable opportunities, from having coasted along Lake Winnipeg and the other lakes that lie in this formation, gives an interesting account of its development in his recent work ('Canadian, Assineboine, and Saskatchewan Expl. Exped.' ch. xxxviii.): his fossils having been submitted to Mr. Billings of the Canadian Geological Survey, the following groups were identified as occurring in the Winnipeg basin; all of them are Lower Silurian:—

1. Chazy Formation.
2. Bird's-eye Limestone.
3. Trenton Limestone.
4. Hudson River Group.

Of these I only saw the last at the same place that Dr. Owen examined and recognized the proper age of the beds in 1848—namely, at the Lower Fort Garry on Red River. Here there is a bench of magnesian limestone exposed in the bed of the river when the water is low, and which is then quarried for building-purposes. As the river was high when I was there, this section was not visible, but from fragments lying on the bank the following fossils were obtained:—

Cyathophyllum.
Columnaria alveolata (*Hall*).
Favestella (Favosites basaltica of *D. Owen*).
Receptaculites occidentalis (*Salter*).
Ormoceras Lyonii (*Stokes*).
Strophomena plano-convexa.
Orthis; var. of *O. Lynx*.
Spirifera elegantula.
Maclurea.
Rhynchonella incubescens (*Hall*).

These fossils have been named for me by Mr. Salter, who has kindly examined the few palæozoic fossils that were procured. The limestone is subcrystalline, of a light-buff colour with purple blotches, very hard, and having an angular fracture. At Stony Hill, about fifteen miles north-west from the upper fort, there is an isolated bluff of limestone rising from the plain-level to the height of 80 feet. The south and western exposures are abrupt and waterworn, it having evidently been at one time an island; and indeed during the great floods which have several times inundated the settlement it has been one of the few spots upon which the inhabitants can take refuge, reaching it by means of boats. The beds of limestone are horizontal or nearly so, and are slightly different from those at Fort Garry in their mineral aspect, having a more crystalline structure and the colour being of a reddish hue. No fossils can be discovered in newly fractured portions, but on the weathered surfaces a few obscure remains of fossils are to be seen projecting, together with siliceous and gritty particles, from a dull floury surface.

The Silurian rocks have now been traced continuously from Lake Superior west of the sources of the Mississippi, and thence into the valley of Lake Winnipeg and on to the Arctic Ocean, skirting the more ancient axis. On the shore of Lake Winnipeg they have been observed much disturbed and even vertical by Dr. Owen ('Report on Geol. of Minesota,' &c.), but in general they rest nearly horizontally, or with only a very slight dip.

Resting on the Silurian strata, Mr. Hind has detected limestone with Devonian fossils in a tract to the west of Lake Winnipeg, where there are copious salt-springs, the brine from which is used for the manufacture of salt. He considers the line marked by the occurrence of these salt-springs to indicate the outcrop of the Devonian strata.

The route of the Expedition at once passed from Silurian to Cretaceous rocks without any indications of the intervening formations until reaching the Rocky Mountains.

STRUCTURE OF THE ROCKY MOUNTAINS.

Physical Character.—The plains at the eastern base of the Rocky Mountains are, as I have before stated, elevated above the sea 4000 feet; and, as the average limit of vigorous vegetation in that latitude is attained at 5000 to 6000 feet, the greater mass of the mountains displays in consequence naked and bald surfaces, which are generally very precipitous. Their structure is thus easily discerned to be of strata the real thickness of which, originally very great, has been much exaggerated by the complex flexures which cause the beds to recur again and again, sometimes even in the same mountain. The apparent confusion is so great from this cause as to strike the eye at once, and it is not until observations have been made over a considerable extent of the range that the extreme regularity with which the disturbing agencies have been exercised becomes evident. The flexures of the strata on the eastern part of the mountains have been so completely inverted that the prevailing dip is towards the centre of the mountains—that is, to the W. and S. The strike of the plications varies, but in a regular manner. From Bow Fort, southwards, it is only a few degrees east of south; but north of that river to the valley of the North Saskatchewan its average direction is S.S.E., and between that valley and the Athabasca it is S.E. nearly, while to the north of that it is changed to within two points of east and west. These changes in the direction of the strata take place at the different great valleys by which these rivers leave the mountains, and which probably mark the lines of transverse fracture. The mountains are divided into groups by great longitudinal valleys, which are met with in every part of the chain that I examined, running in the length of the range and forming a part of each of the river-systems. The course of these rivers is, therefore, in every case zigzag, alternately flowing through wide valleys either to the north or south, and then making short breaks to the east or west through narrow and rugged defiles.

Throughout these great valleys it seems to be the arrangement of the detrital deposits that has in many cases determined the direction in which the rivers flow.

A curious feature is to be remarked in the position of the watershed between the waters of the Pacific and those of the Atlantic, arising, no doubt, from this cause. It is found gradually to occupy a position further to the west, and through the chain, so to speak, as the rivers rise more to the north.

Thus the Missouri can hardly be said to rise within the Rocky Mountains at all. Belly River, on the boundary-line, rises from the first ridge before reaching the first longitudinal valley. Kananiskis River rises in that valley, or from the second range; Bow River from the third range; the North Saskatchewan from the fourth range; the Athabasca from the fifth; and, although I have not seen Peace River, the one further to the north, still this feature is so well marked that it has been spoken of as rising on the west side of the Rocky Mountains and then cutting through that range to the east. This all tends to show that we must not look on the Rocky Mountains as a continuous range, stretching as a line of fracture through the length of the continent, but rather as a succession of centres of disturbance, a fact which has been amply proved within the American territory.

Thus what are known as the Rocky Mountains at the head of the Missouri are rounded off to the north and south, losing their character of a lengthened range in that of a mass of mountain-country.

In like manner the Rocky Mountains within the British territory must be looked upon as a mass with its longer axis lying N.N.W. and S.S.E., with which the main strike of the strata conforms.

Geological Structure.—There are three of these great longitudinal valleys that are more persistent than the others, each of which marks a change in the formations which compose the mountains. As far west as the first of these, the structure of the mountains may be understood from the sections*, figs. 11 & 12. The strata are of thick-bedded limestones. These limestones are of dark and light-blue

* All these sections are merely diagrams combining the results of detached observations.

colour, crystalline, compact, or cherty, with fossils that are of Carboniferous age. In the sections these limestones are lettered *b*.

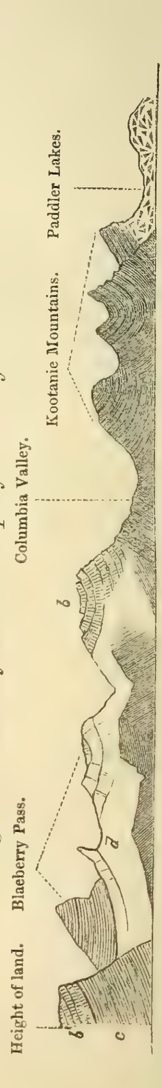
Fig. 11.—*Section along Bow River within the Rocky Mountains.*

a. Mesozoic strata. *b*. Carboniferous strata. *c*. Devonian strata.
d. Quartzites and conglomerates (Silurian?). *e*. Talcose slates with quartz-veins.

Fig. 12.—*Section along the North Saskatchewan River, within the Rocky Mountains.*

a a. Mesozoic strata and Ostrea-shales. *b b*. Carboniferous strata. *c c*. Devonian strata. *d*. Silurian (?) strata.

Fig. 14.—*Section of the West Slope of the Rocky Mountains.*



b. Carboniferous strata. *c*. Devonian strata. *d*. Silurian (?) rocks. *e, e'*. Schists. *f*. Granite.

Along with them are softer beds of gritty sandy shale, generally of a dull-red or purple colour; and the irregular disintegration of these two groups of strata produces the rugged appearance of this range, the mountains being in general formed by masses of synclinal folds, while the valleys mark anticlinal fractures. The valley between the first and second range marks a great trough in the strata in which patches are preserved of chocolate-coloured ferruginous shales with beds of grit and layers of ironstone, and which are the same seen in the above sections resting on the flanks of the limestone mountains, belonging to a more recent formation, and to which I have previously alluded (p. 427). In the second range we have the same limestones and shales repeated as in the first; but at the base I observed traces of a magnesian limestone of a buff colour, containing *Atrypa reticularis*, a true Devonian fossil (*c*, fig. 11). Towards the west this range everywhere in the mountains presents a sheer wall of vertical limestone, the ragged edge of the beds forming the Saw-back Range. The change in the look of the mountains that now takes place may be well seen, as on Bow River in fig. 13, where the east side of this

Fig. 13.—*Sketch of the Second Great Valley, on Bow River, in the Rocky Mountains.*

valley consists of vertical strata, while on the west side the mountains are formed of cubical masses of strata that are almost horizontal. These are of hard quartzite-sandstone, passing into conglomerate, and capped by hard limestone, with the ferruginous shales resting obliquely on their sides at the line of fracture. At the source of the Pipe-stone Creek the mountains form part of the second range, and there I procured some fossils that have been distinguished by Mr. Salter as *Orthis*, *Lingula*, *Euomphalus*, and from the limestone *Lithostrotion*, which are either Carboniferous or Devonian. On the Athabasca River gneissoid rocks, traversed with quartz-veins, were observed to form the floor of the second longitudinal valley, and in descending the valley of Vermilion River, and also that of Blaeberry River, talcose shales were met with also, forming the floor of the valley (*e*, figs. 11 & 14). On Kicking-horse River in the third range, we have the mountains again formed of blue limestone, together with a compact blue schist with red bands, giving a curious striped aspect to the rock. This schist or slate-rock forms the highest points of the mountains in the above district (*d*, fig. 14).

The third longitudinal valley is that in which the Columbia and Kootanie Rivers flow in opposite directions parallel with the range. Along the eastern shore of the Columbia Lakes we find the mountains again composed of the Carboniferous limestones which form the eastern ranges, but resting unconformably on slates (*e*, fig. 14).

At the source of the North Saskatchewan the mountains are very massive, and are principally composed of a deep-blue compact limestone, that often contains nodules of iron-pyrites (*c*, fig. 14). A few specimens of *Atrypa* (*reticularis*?) and *Athyris* lead Mr. Salter to regard these limestones as Devonian. To the west of the great Columbian valley the strata were only seen in descending the Kootanie River, as shown in the section, fig. 14. That river breaks through a succession of well-defined ranges that never rise to any great altitude, and are composed of dark schists (*e'*), traversed by quartz-veins, the whole forming beautifully developed flexures. Some miles east of Padler Lake the slates (*e*) were again seen underlying these schists, and at that place commences a district of granitic country (*f*), where mountain-ridges rise as rounded masses to the height of 800 to 1000 feet above the general level.

Towards Fort Colvile the Kullespellem Mountains bound the Columbia to the east, and are formed of quartzose slates in thin beds, limestone partly altered, and serpentine. At the south end of the Kulespellem Mountains the great trap-floes of the Columbian Plains commence, and are there seen to overlie the granite and other strata, filling up the hollows in their surface.

The horizontal extent of these lava-floes is truly wonderful, as they occupy nearly the whole surface of the great Columbian Desert without any chain of mountains or peaks existing to which their origin can be referred.

This great plain is frequently cut by chasms 500 to 600 feet deep, the sides of which expose stratum after stratum of thin lavas intercalated with softer tufaceous beds, the whole being quite horizontal. The lava-floes have often a columnar structure, especially in the neighbourhood of depressions in the plain, such as Sil-kat-kiva Lake, which probably mark the position of ancient craters. At some points up Snake River, American parties have procured Tertiary fossils from the tufaceous limestone that underlies these basalts.

The whole way to the Dalles the Columbia flows through an enormous chasm in these stratified lavas and tufas, giving rise to most wonderful scenery. Often the whole of this mighty river is compressed between perpendicular walls of basalt, but with a channel of such depth that its treacherously swift current preserves a glassy surface.

CASCADE RANGE.

Where the Columbia breaks through the Cascade Range there is a great rapid rather than a fall, from which the mountains have derived their name, and connected with the formation of which there is an old Indian legend. The river from the Dalles to this point, a distance of forty miles, is almost without current, and bounded by a perpendicular wall of mountains on either hand, and the story is, that at one time the river had a uniformly swift current the whole way, and that where the Cascades now are, it then passed under a gigantic natural arch that crossed from side to side of the chasm. During a great earthquake this arch fell down, and now remains as the chain of islands across the head of the Cascades, while the river has gradually carried down the fragments so as to form the long rapid. The river was thus dammed back all the way to the Dalles, and submerged the forests along its banks, the stumps of which are still to be seen sticking out of the water at a distance of several hundred yards from the shore. The stumps of the submerged trees are of a species that never grows near water; and as the other conditions of the story agree remarkably well, I am inclined to think there may be some truth in it. It was told me, as we were passing the spot, by a fellow-passenger who had been a long time among the natives as an American Indian agent; and I have since heard it from gentlemen who have been twenty-five years in that country in the Hudson Bay service.

In descending from the Cascades to Vancouver, stratified rocks are seen perched on the flanks of the mountains, among which is a group of strata of a bright vermilion colour. Along the valley of the river there are also strata of tufaceous sandstone and clay which are only slightly disturbed. At the Cascades the beds attain a considerable thickness and contain large fragments of silicified wood. The scenery of the Lower Columbia before reaching the flat district around Fort Vancouver is exceedingly fine, the river passing, successively, bold promontories more than 1000 feet in height, and sometimes under lines of cliff over which rivulets pour as cascades from a height of 600 feet. Between the Olympic or Coast Range, which stretches to Cape Flattery, and the Cascade Range, the great valley of Puget Sound is continued south as far as latitude 44°, first as far as the Columbia River by the Cowlitz Valley, and then by the valley of the Willamette, and presents a long strip of valuable country, which forms the only good part of Oregon and Washington territories. The River Columbia crosses this strip of country, only conforming to its direction for a short way from Vancouver to the Cowlitz.

Of the Olympic Range I believe nothing is known; but, as viewed from Puget Sound, the outline of these mountains reminded me in a striking manner of that of the exterior ranges of the Rocky Mountains, where they are composed of plications of stratified rocks.

I have previously mentioned the metamorphic rocks, with beds of crystalline limestone, that form the mass of Vancouver Island; and for further interesting details respecting the south end of the island, reference may be made to Mr. Bauerman's paper, published in the Society's Journal, Nov. 1859.

APRIL 24, 1861.

Daniel Mackintosh, Esq., Chichester, and Richard Payne Cotton, M.D., F.R.C.P. Lond., 46 Clarges Street, Piccadilly, were elected Fellows.

The following communications were read:—

1. *On the Occurrence of the* Cyrena fluminalis, *together with* Marine Shells *of* Recent Species, *in* Beds *of* Sand *and* Gravel *over beds of* Boulder-clay *near* Hull; *with an Account of some* Borings *and* Well-sections *in the same District.* By Joseph Prestwich, Esq., F.R.S., Treas.G.S., &c.

Few fossils of its class can lay claim to the interest that has attached to the *Cyrena fluminalis.* This small bivalve shell, described in 1834 by Mr. Searles Wood as the *Cyrena trigonula* of the Norwich Crag, and afterwards identified with the *C. consobrina* of Caillaud, now living in the Nile and parts of Asia*, has, from the circumstance of its occurrence in beds of well-defined position beneath the Boulder-clay of Norfolk, been ranked as pre-eminently a præglacial shell, and as the associate of the *Hippopotamus major* and *Elephas antiquus.*

On the strength of the palæontological argument, certain isolated beds containing the same *Cyrena,* including more especially the well-known deposits of the Thames Valley, the immediate relation of which to the Boulder-clay is not apparent, were referred to the same præglacial period. The late Mr. Trimmer, Mr. Morris, and myself have, however, always held a different opinion, inclining to the belief that these latter deposits were of later date than the Boulder-clay. Our reasons being mainly based upon the general physical phenomena, and wanting the more positive proof of superposition, the age of these deposits remained a point at issue between geologists and palæontologists. But if the determination of age were already desirable on the abstract geological question, it is now of much more importance in consequence of the circumstance of the same *Cyrena* having lately been found in the neighbourhood of Abbeville in the beds of sand and gravel containing Flint Implements†.

So much of the palæontological argument as hinges on the occurrence of the *Elephas antiquus* in these beds has lost its weight, inasmuch as this species, instead of occurring invariably in beds beneath those containing the *Elephas primigenius* and always apart from it, has now been found associated with it in positions which leave little doubt of their original contemporaneity. The *E. antiquus* may have lived before the *E. primigenius*; but it certainly appears to have lived on to the period of the latter species, which, the evidence I have collected goes to show, was probably not introduced into this country until after the Boulder-clay period.

The *Cyrena,* although found in various beds supposed to be newer than the Boulder-clay, could not be proved in any of these cases to be newer by direct superposition. In the course of last summer, however, I obtained proof of its presence in beds considerably higher, at all events, than the Mammaliferous or Norwich Crag. I had visited

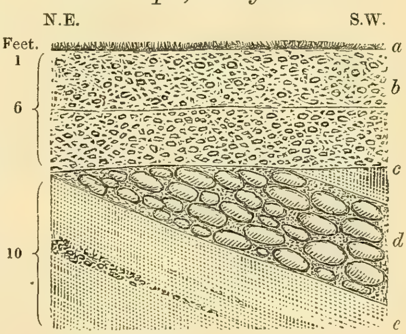
* See the account given of the range of the living shell, by Mr. Woodward, in the Zool. Proc. 1856, p. 187.

† The first *Cyrena* found there I took out of a bed of sand overlying a bed of subangular flints, in which I at the same time found three flint flakes or knives: larger lance-head-shaped flint implements have been found in a still lower bed of gravel adjoining the town-walls. Four more specimens of the *Cyrena* have since been found in some sands. (See section in the Phil. Trans. for 1860. p. 284.)

Hull and examined the Boulder-clay of the Yorkshire Cliffs, when my attention was drawn to the single valve of a *Cyrena fluminalis*, identical with the Grays species, in the fine collection of organic remains of Mr. Leckenby, of Scarborough, and long known to Mr Morris. Mr. Leckenby informed me that it came from the shelly gravels described by Professor Phillips near Hull, where it was not rare.

Returning to Hull and following the instructions given in Prof. Phillips's 'Geology of Yorkshire' (vol. i. p. 23), I found my way readily to the gravel-pit, one mile south of Ridgemont near Hedon, therein described. Professor Phillips gives a list of eight shells from this locality, and also notices the common occurrence of another shell which he could not refer to any then described species, and which proves to be this *Cyrena*. The section is small; and although the superposition of the beds is not shown, they are justly inferred by Prof. Phillips to be closely connected with the Boulder-clay. To the S.W. of this pit are several old pits, now nearly obscured, to which I shall revert presently. My attention was then directed to a large ballast-pit on the Hull and Holderness Railway, one mile S.S.W. from the above-mentioned pit, and 8½ miles eastward of Hull. There is no name given to the spot on the Ordnance Map, but locally it is known as "Kelsey Hill." The section at this spot is extremely interesting. It exhibits great beds of coarse gravel and fine shingle interstratified roughly and irregularly with beds of sand—the whole of a light colour, and with much oblique bedding. In places there are no shells; in other places they are most abundant The following sections give the general characters of the deposit.

Section at the East End of the Ballast-pit, Kelsey Hill.



a. Gravelly soil.
b. Rather coarse gravel.
c. Sand and fine gravel.
d. Gravel composed of small rounded boulders mixed with shells, 5–6 feet.
e. Light-coloured sands, with shells, chiefly in fragments.

The gravel in the upper beds consists of subangular flints with pebbles of the older rocks, but the latter are in far larger proportion in the lower part of the section, some beds consisting almost entirely of small boulders of granite, greenstone, quartz, porphyry, mica-slate, limestones, sandstones, lias, and hard chalk, together with very large flints*. They are almost all worn and subangular, and many are perfectly rounded. Some specimens are above a foot in length. A few of the limestone blocks retain faint traces of glacial scratching. Many of the blocks of chalk are drilled with Annelid borings and perforated with the holes of the *Pholas crispata*. Some few of the rock-blocks and many of the large

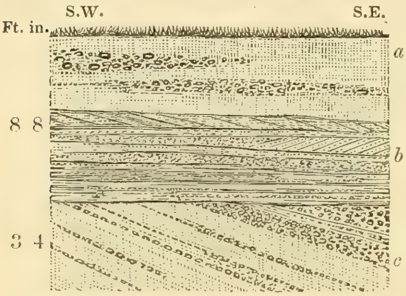
* See 'Geology of Yorkshire,' 2nd edit. p. 20–23, for fuller details of the lithological character of the strata.

flints, however, are angular. The large gravel, *d*, contains with the sand in the interstices between the boulders a certain number of the shells hereafter named*.

Towards the central part of the pit, now in course of being worked, the gravel is finer and the shells more numerous and perfect. So abundant are the shells and so regular the bedding, that in the following section the deposit has quite a Crag-like appearance.

Some 3 or 4 feet of a larger and coarser gravel has been removed from the top of this section. The shells in *b* are extremely numerous,—the *Tellina*, *Cardium*, *Mactra*, *Buccinum*, *Littorina*, *Nassa*, *Natica*, and *Purpura* preponderating, with the *Cyrena*, which hardly yields in abundance to any of the others. The *Anomia*, *Corbula*, *Nucula*, *Venus*, *Murex*, and *Fusus* are rare. Almost all the shells are worn, and have the appearance of having been dead shells cast up on a beach or a bank. The bivalves are more perfect than the univalves, which are for the most part more or less broken, especially the large *Buccinum*. Generally the shells are but little decomposed, many of them retaining even some of their colour.

Section close-adjoining the Railway at the Ballast-pit, Kelsey Hill.



a. Gravel and sand.
b. Fine gravel and sand, with veins of coal-smut, full of shells.
c. Sand and gravel, in oblique layers and with fewer shells.

I am indebted for the following revised list† and remarks to Mr. J. Gwyn Jeffreys, F.R.S., F.G.S., &c.

MOLLUSCA.

[These are alphabetically arranged, but according to the nomenclature of Forbes and Hanley. The species marked with an asterisk are not in their list.]

No.	Species.	Remarks on the comparative frequency, &c.
	Bivalves.	
1.	Anomia ephippium	A single valve, noticed by Mr. Leckenby.
2.	Astarte compressa	A fragment.
3.	Cardium edule	Common: the ordinary form.

* Another locality mentioned by Professor Phillips is Brandesburton, 15 miles northward from Kelsey. I had not time to visit this place, but my friend Mr. Smith, of Hull, has recently been there, and he reports to me that the gravel forms a ridge of low hills which have been worked for centuries. At the pits now open, shells are very scarce. The specimens he has sent me are only worn fragments of *Cardium edule*, *Tellina solidula*, and *Pholas crispata* (?). The locality, however, is important as showing more distinctly than at Kelsey Hill the superposition of the gravels in the Boulder-clay; for at the village a deep well has been sunk, which, after passing through the lower 10 or 12 feet of gravel, traversed 60 feet of clay with stones (Boulder-clay); below this was a bed of flinty gravel, and then the Chalk at a depth of about 80 feet.

† This list is more copious than the one I first gave, and is the result of an ex-

No.	Species.	Remarks on the comparative frequency, &c.
	Bivalves.	
	Cardium edule, var.	An estuarine or brackish-water form; more produced at the anterior side and thinner: less frequent than the last *.
4.	Corbula nucleus	Rare.
5.	Cyprina Islandica †	A fragment.
*6.	Cyrena fluminalis, *Müller*	Abundant. *Corbicula fluminalis* of conchologists. Some specimens are larger than recent ones of the same form.
7.	Mactra solida	Not common: a small variety, intermediate between this species and *M. elliptica* of Brown, which I consider a variety of it.
8.	——— subtruncata	Not common. The lateral teeth in this and the last species are perpendicularly striated, as in *Cyrena.*
	——— ———, var.	Rare. The Irish deeply striated form.
9.	Mya truncata	Two fragments.
10.	Mytilus edulis	A few fragments.
11.	Nucula nucleus	A fragment.
12.	Ostrea edulis	Rather common: not of any size. Apparently an estuarine form.
13.	Pholas crispata	A few fragments.
14.	Tellina solidula	Very abundant, but not of any size.
15.	Venus striatula	A single valve.
	Univalves.	
16.	Buccinum undatum	Very abundant: a northern form, having the ribs more obliquely carved.
17.	Dentalium entale	Not common.
18.	Fusus gracilis, *Da Costa*	A fragment. This is the *F. Islandicus* of Forbes and Hanley, who appear to have mistaken Da Costa's species for the *F. Islandicus* of Chemnitz. These species are very distinct.
19.	—— antiquus, var. despectus	An immature specimen and a fragment of another. In this country it occurs only in the south of Ireland and in Zetland.

amination just made by Mr. Jeffreys of my original collection, as well as of a further series collected by Mr. Smith, and sent me only a few days since. It will be seen by my observations which follow those of Mr. Jeffreys, and which remain as they before stood, that our conclusions, which are based upon independent grounds, are in very close agreement.—21st Oct. 1861.

* In Mr. McAndrew's Report to the British Association, in 1856, on certain dredging operations, he says (p. 134), "Near Tunis a narrow neck of land divides the bay from a shallow salt-water lake, at the head of which the city of Tunis is situated; on the one side of this neck of land (that facing the bay) all the specimens of *Cardium edule* were strong, triangular, and with few ribs, while on the other side, towards the lake, they were thinner, wider, and much more numerously ribbed. The northern varieties attain the largest size."—J. G. J.

† This may have been washed out of some of the lower beds of the Boulder-clay, where such fragments are often common. So also the fragment of *Astarte compressa.*—J. P.

No.	Species.	Remarks on the comparative frequency, &c.
	Univalves.	
	Fusus antiquus, var. sinistrorsus	One specimen, exactly resembling the common Crag shells. It is very rare as recent or living in these seas.
20.	Lacuna crassior	Very rare.
21.	——— vincta	Several specimens. One of them is of unusually large size.
22.	Littorina littorea	There is only one specimen which I can refer to this species, and that is not perfect.
23.	——— rudis	Only one small specimen.
*24.	——— squalida, *Brod. & Sow.*	Rather common. An Arctic form. It is the same species as occurs in the newer Crag strata. Intermediate between *L. littorea* and *L. rudis.* Probably the *L. limata* of Lovén.
25.	Mangelia nebula	Three imperfect specimens.
*26.	——— pyramidalis, *Ström.*	Two young specimens. A Norwegian species.
27.	——— turricula	Several specimens.
28.	Murex erinaceus	A fragment. Neither this, nor *Mangelia nebula,* is known to me as an arctic species.
29.	Nassa reticulata	Frequent.
	——— ———, var. scalariformis	One specimen.
*30.	Natica clausa, *Brod. & Sow.*	A few specimens; one is very large. A northern species.
31.	——— Groenlandica, *Beck* (pusilla, *F. & H.*)	Three specimens—one large—and a fragment of another still larger. It survives on the Doggerbank.
32.	——— helicoides	Rare. Found living with the last on the Doggerbank.
33.	——— nitida	Not common.
34.	Purpura lapillus	Very abundant.
35.	Rissoa labiosa	A fragment.
*36.	——— subumbilicata, *Mont.*	Two imperfect specimens. An estuarine species, allied to *R. ulvæ,* of which it may be only a variety.
37.	Trophon clathratum	A few specimens, of large size.
*38.	——— Gunneri, *Lovén*	Two specimens; Norwegian.
*39.	——— scalariforme, *Gould*	Two specimens; northern.
40.	Turritella communis	Two fragments.
	Cirrhiped.	
	Balanus crenatus, *Bruguière*	Detached valves are rather common.

Although nearly all of the species comprised in the foregoing list still exist in the German Ocean, there are some which are only known as living in more northern seas.

Mr. Jeffreys further observes, "The conditions of coast and sea-bottom which produced these animals appear to have been as follows.

"1st. A muddy estuary, like the Solent, into and out of which a large river flowed, and in which grew the *Zostera marina*: this estuary and river were inhabited by the *Rissoæ, Lacuna vincta,* the variety of *Cardium, Tellina solidula,* the *Cyrena* (or *Corbicula*), and probably the *Ostrea*; the shells being carried down into the sea by the river.

"2nd. Below the beach, referred to underneath, a belt of loose stones of different sizes, with patches of mud; and here lived the *Purpura, Mytilus, Nassa, Littorinæ,* and *Balanus.*

"3rd. An exposed patch of chalk, which produced the *Pholas.*

"4th. A wide and deep patch of sand with gravelly mud, inhabited by the typical *Cardium,* the *Mactræ,* and the *Mya.* Only uncovered at low spring-tides.

"5th. Seaward, at a depth of from 20 to 30 fathoms, and at a distance of not more than two or three miles from the shore, where the ground was sandy, we might expect to find the *Buccinum, Fusi, Naticæ, Corbula, Nucula, Astarte, Venus, Dentalium, Lacuna crassior,* variety of *Mactra subtruncata,* the *Tropha,* and *Mangeliæ.* All these were within the range of the tidal current, and may have been thrown up on a pebbly beach, which would account for their generally broken and rolled condition."

In addition to the above I may notice the occurrence of a few small *fish vertebræ* and of *annelid* borings in the pieces of chalk. I was informed that some large bones* had been found two or three years since; but the only trace of bone I found was an undeterminable fragment reduced to a pebble-form.

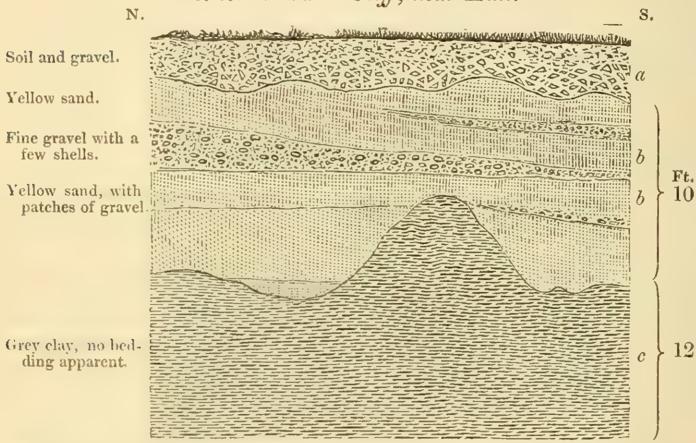
As it would appear that none of the shells are in their original habitat, it becomes a question whether they are all contemporaneous, and of the same date as the gravel in which they are imbedded. With one or two exceptions I am inclined to answer in the affirmative. The shells are alike in mineral condition, and they show the same amount of wear. They do not seem to have been transported far, or subjected to very much rolling about. If any had been washed out of an older cliff, then we should look for more or less difference of wear and of mineral condition between such introduced specimens and the more recent specimens; but no such distinctions are apparent. All the species, with the exception of the *Cyrena,* are such as might live in the same sea, and have the ordinary appearance of dead shells cast up on a gravelly bank or on a beach. The *Cyrena,* however, being a freshwater shell, must either have been washed out of an older deposit or else carried out to sea from the rivers which it inhabited. With this fossil also there is nothing on the score of wear and mineral condition to distinguish it from its present marine associates. As these latter indicate a certain amount of transport and intermingling by marine currents, the same cause has in all probability operated along the whole littoral area and caused the intermingling, not only of the shells of different zones of depth, but also of those brought down by streams. That there were such freshwater streams in the vicinity

* Professor Phillips mentions the occurrence of the tusk of an Elephant in similar beds at Brandesburton (Geology of Yorkshire, 2nd edit. vol. i. p. 22).

of this area, is indicated by some of the above-mentioned marine shells exhibiting varieties peculiar to brackish waters *. It is to be observed, nevertheless, that no other freshwater shells nor any land-shells are found in the Kelsey Hill beds; but this may arise from the strength and solidity of the *Cyrena* being superior to that of the ordinary freshwater and land-shells. Its numbers are also remarkable. It occurs literally in thousands. For these reasons I am inclined to believe it to have been contemporaneous with the marine shells with which it is found associated.

With regard to the position of the Kelsey Hill gravels, the coast-section from the Humber to Bridlington shows cliffs of Boulder-clay capped here and there by similar gravels, but not so fine and sandy. Well-sections throughout Holderness also show the Boulder-clay to

Section at Paull Cliff, near Hull.



extend inland to Hull and Beverley. As this clay could not be seen beneath the gravels at Kelsey Hill, I proceeded to examine the river-side section described by Professor Phillips at Paull Cliff, a few miles below Hull. I there found several of the same shells (including the *Cyrena*, but in much fewer numbers and more broken) in beds of sand with but little gravel, reposing upon an irregular surface of grey clay; but, this clay containing no boulders or fossils, I could not feel certain about its being the Boulder-clay.

As I could not remain to superintend a series of trenches and borings which seemed necessary to settle the question of superposition, my friend Mr. T. J. Smith, F.G.S., of Hull, who had accompanied me on my last visit to Kelsey Hill and also to Paull Cliff, undertook to see them carried out; and I am indebted to his active co-operation for the following results. The difficulties, however, were greater than we anticipated, and the results less. Owing to the wet season it was found impossible to dig a trench to any depth at Kelsey Hill;

* The occurrence of the two species of *Rissoa* has now to be noticed.

for the line of water-level was reached at a foot or two below the level of the pit. Boring was then tried, when, owing to the variable and often very coarse structure of the gravel, the first workmen gave it up in despair. It was resumed again at a later period with the obliging assistance of Mr. Monkman, the manager of the Holderness Line, whose property the pit is. We had hoped to find the base of the gravel at a depth of 10 to 12 feet; whereas after penetrating with difficulty to a depth of 36 feet, always in the gravel, but the lower bed more argillaceous, the work had to be abandoned. These borings at Kelsey Hill gave:—

Boring at Kelsey Hill.

Commencing at the base of the section shown at p. 448	Sand and gravel with shells	4 feet
	Larger gravel	16 "
	Smaller gravel	8 "
	Larger gravel in grey loam (Boulder-clay?)	8 "
		36 "

I may observe, that although we failed to obtain the desired exact proof at this spot, yet at places close adjacent, and on the same level, artesian wells have been sunk which invariably pass through a greater or lesser mass of Boulder-clay before reaching the water-bearing beds of sand or the chalk*.

Attention was now turned to Paull Cliff, to ascertain whether or not the clay exposed at the base of the cliff belongs to the Boulder-clay. Such proves to be the case; for in digging below the base of the cliff, Mr. Smith soon found the clay to become stony, and the specimens he has sent me have the ordinary aspect of the Boulder-clay.

Section at Paull Cliff.

Cliff-section, at a short distance from the sect. p. 452	Soil and silty gravel	8 feet.
	Sand and gravel with shells	12 "
	Sandy dark-coloured clay without stones	6 "
Section obtained by digging at the foot of the cliff.	Clay with stones (Boulder-clay).	

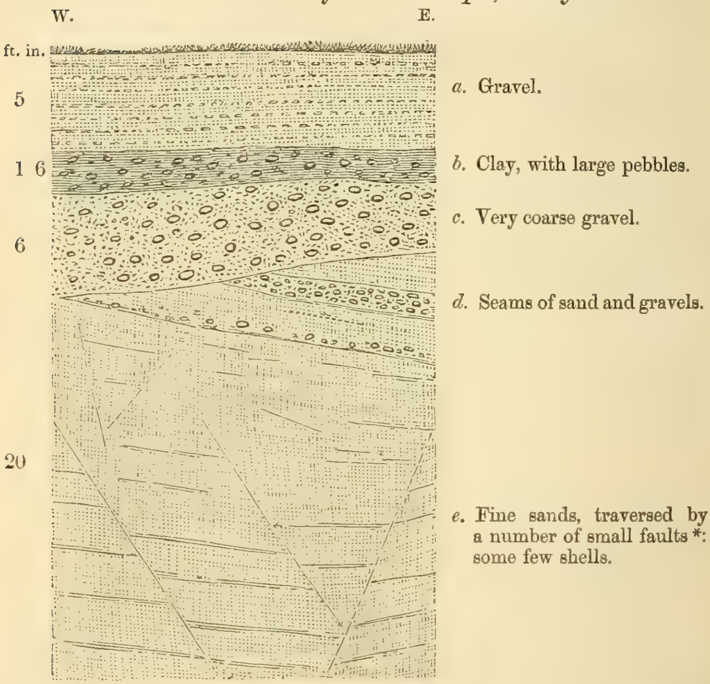
Looking therefore at all the conditions of the case, I feel satisfied that these gravels with the *Cyrena fluminalis* overlie the great mass of Boulder-clay of Holderness. The question then arises as to whether these shelly gravels belong to the Boulder-clay, or whether they are separable from it; and on this point the evidence is not quite clear, although I am now more inclined than at first to consider it tolerably conclusive. As observed by Prof. Phillips, there are places on the coast where patches of sand and gravel are seen intercalated in the clay, whilst inland the gravels form isolated hills, and the

* At Hull the section of a well given by Professor Phillips shows a clearer separation of the beds, these being—

Alluvial accumulations	32 feet.
Boulder-clay	36 "
Sand	26 "
Chalk	16 "
	110 "

difficulty is at these places to obtain the positive evidence of superposition. At the pit first mentioned, near Ridgemont, the gravel is continuous throughout, and no Boulder-clay is seen; but at the adjacent old pit I found distinct traces of a bed of *red clay* capping this gravel, whilst at Kelsey Hill the high face of sand and gravel at the west end of the pit shows a slight intercalation, near the top, of a bed, 1½ foot thick, of *pebbly clay*. There is also some higher ground in the neighbourhood which seems capped by clay.

Section at the west end of the Ballast-pit, Kelsey Hill.



Taking this section in conjunction with the boring, we have here a thickness of 60 feet of sands and gravels†. This, it is true, is unusual on the coast, and it might be asked whether these upper beds of gravels and sand are not reconstructed out of the clays and gravels of the Boulder-clay. It has, however, to be observed that in this more inland portion of the Boulder-clay it would seem that the beds of gravel and sand are altogether more generally developed—a fact shown in the two following and other well-sections, for which I am indebted to Mr. Smith.

* The middle part of the section is so obscured that I could not ascertain whether the faults proceeded upwards through the beds *d* to *a*.

† The hillock rose in one part (now removed) 56 feet above the marshes.

Section of two Borings near Hedon, six miles from Hull and about two miles from Kelsey Hill.* (Furnished by the Engineer of the Hull Waterworks.)

At Old Pollard Farm.

	Feet.
Soil	2
Red brick-clay	4
Black warp	34
Red clay full of stones	20
Rough gravel with sand and spa-water	26
Very fine clay, clear of stones	8
Bed of flint	2
Black Moor, decayed wood	2
Blue clay with white sand	1
Blue clay with white marl	8
White marl-clay with small cobbles and flints	9
Chalk with bed of sand	5
Chalk clear of flint	69
	190

At Twier's Farm.

	Feet.
Soil	2
Good brick-clay	5
Black warp	13
Strong marly clay with stones	40
Rough gravel-stones and spa-water	24
Fine clay	1
Dark-green sand	11
Blue clay with white sand	2
Hard mixture of blue clay and white marl	12
Red clay with white marl	10
Chalk	7
White sand which blew up into the pipes 20 feet high	1
Chalk clear of flints	$50\frac{1}{2}$
	$178\frac{1}{2}$

Here beds of gravel occur low down in the Boulder-clay. The upper three beds belong probably to the alluvial deposit of the marshes. The stony clay beneath representing the Boulder-clay, would, if continued on the same level, range under the Kelsey Hill sands and gravels, which therefore, so far as superposition is concerned, might form an upper member of this series. But the gravel is more worn and more shingly than is usual in the mass of Boulder-clay. It has more the character of beach-shingle; for not only have we littoral shells, but rounded blocks of chalk, pierced by Annelids and the *Pholas crispata*, are also common. These are features which I did not notice in the coast-section; nor have I there observed, in those thick beds of sand, the fine lamination and large oblique bedding. These may be owing to the nearer proximity to the mouth of the old river. Further, I found in the coarse gravel of Kelsey Hill pebbles of limestone showing glacial scratches more or less obliterated. These facts therefore afford grounds to view the Kelsey Hill gravels as partly reconstructed beds, deriving some of their materials from the lower beds of the Boulder-clay and associated gravels. The worn and irregular state of the surface of the Boulder-clay at Paul Cliff also gives some support to this partial denudation of the lower beds of the Boulder-clay before the end of that glacial period. On the coast the gravel-beds associated with the Boulder-clay are spread out with more regularity and conformability.

The greater number of shells now obtained from these beds show, however, a more northern character than was at first apparent, and tend therefore, taken in conjunction with the occasional capping of their seams of clay like a Boulder-clay, and the fact of a general

* The terms used by the workmen in these and the other well-sections are retained. The small diameter of the bore-hole, and the presence of water, often render it difficult to judge accurately of the materials.

development of gravels to the westward, to incline me to believe that these beds are to be referred to the upper part of the Boulder-clay. The shells are all of recent species, and 33 out of the 40 are still found on the Yorkshire coast. Nevertheless the presence of such species as the *Natica clausa, N. Grœnlandica, Trophon Gunneri, T. scalariforme, Mangelia pyramidalis,* and *Littorina squalida,* which have a wide northern and Arctic range, indicates colder conditions than those now prevailing on these shores, and more in accordance with what we know of the fauna of this portion of the Post-pliocene series.

I have extended this communication to greater length than I intended, my object having been to make known a very remarkable locality well deserving of further research, and which has an important bearing upon some questions still under discussion. I reserve the more theoretical questions connected with the origin and correlation of the strata to a future more general inquiry.

P.S. I annex a series of sections sent me by Mr. Smith, of borings along the line of railway from Hull to the sea at Withernsea, and passing through Kelsey Hill, which is situated between Sections 3 and 4.

Sections at the stations along the Holderness Railway.

1. *Marfleet,* $2\frac{1}{4}$ *miles from Hull.*

	Feet.
Warp	30

Salt water sprang from "rotten stuff."

2. *Hedon Station,* $5\frac{1}{4}$ *miles from Hull.*

Brick clay	6
Grey marl with stones	24

On to a bed of sand from which water sprang.

3. *Burstwick Station,* $7\frac{3}{4}$ *miles from Hull.*

Brick clay	7
Strong marl with "iron-stone"	29
Strong marl with stones	40

Red sand giving sufficient water.

4. *Keyingham Station,* $9\frac{1}{2}$ *miles from Hull.*

Strong clay	12
Marl with stones	3

Sand-bed with sufficient quantity of water.

5. *Ottringham,* 11 *miles where the Ottringham road crosses the railway.*

	Feet.
Bored through	30

Strong marl with stones; not finding water, was given up.

6. *Winestead Gate-house,* $13\frac{1}{2}$ *miles.*

Warp	30
Strong red marl	5
Marl with stones	30

Dirty sand containing water.

7. *Patrington Station,* 14 *miles.*

Strong red marl	30
Grey marl with stones	15

Sand with water.

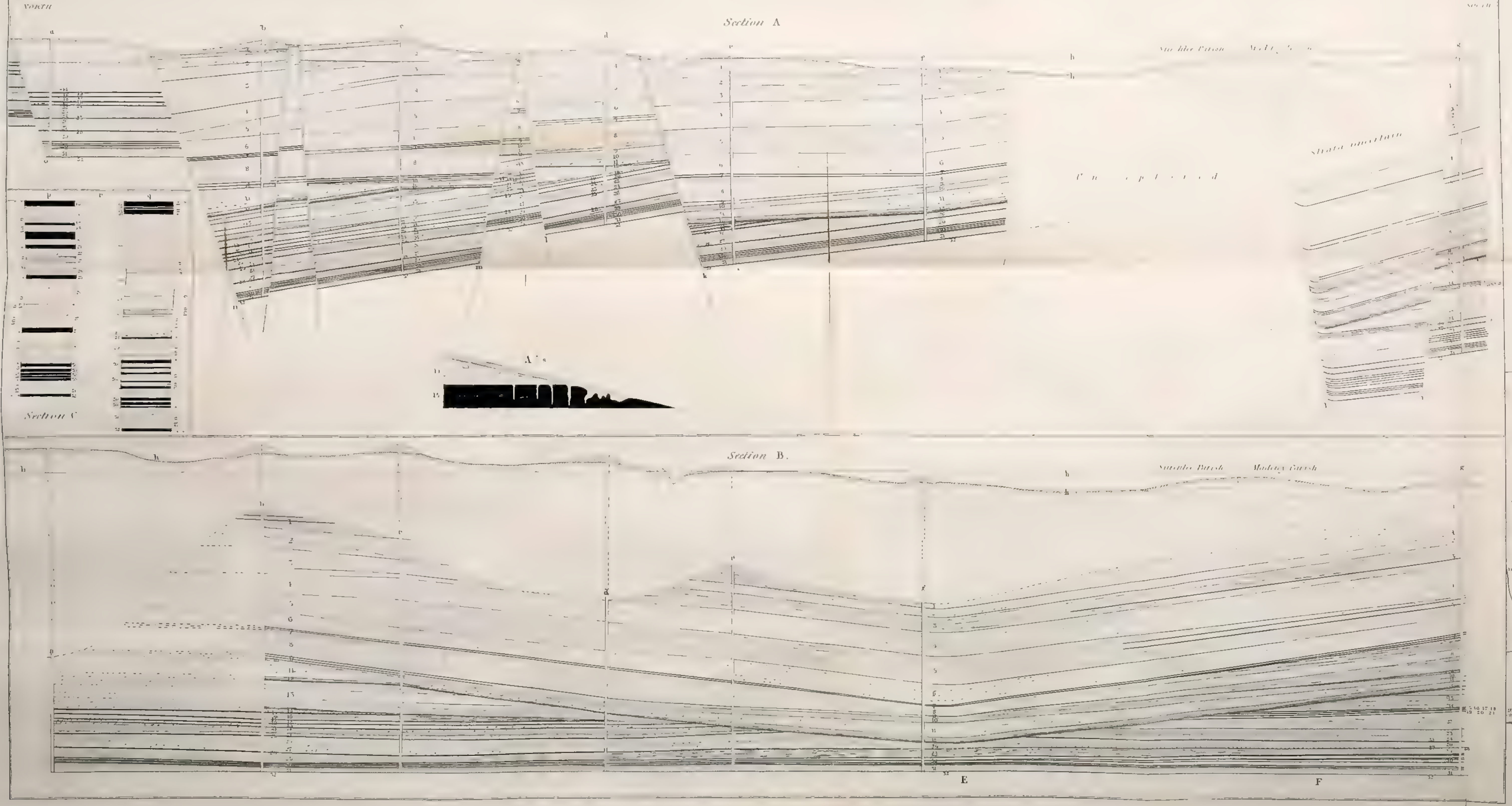
8. *Withernsea Station.*

Clay marl	15
Gravel and sand	5
Strong marl with stones	60
Grey sand and shells	2

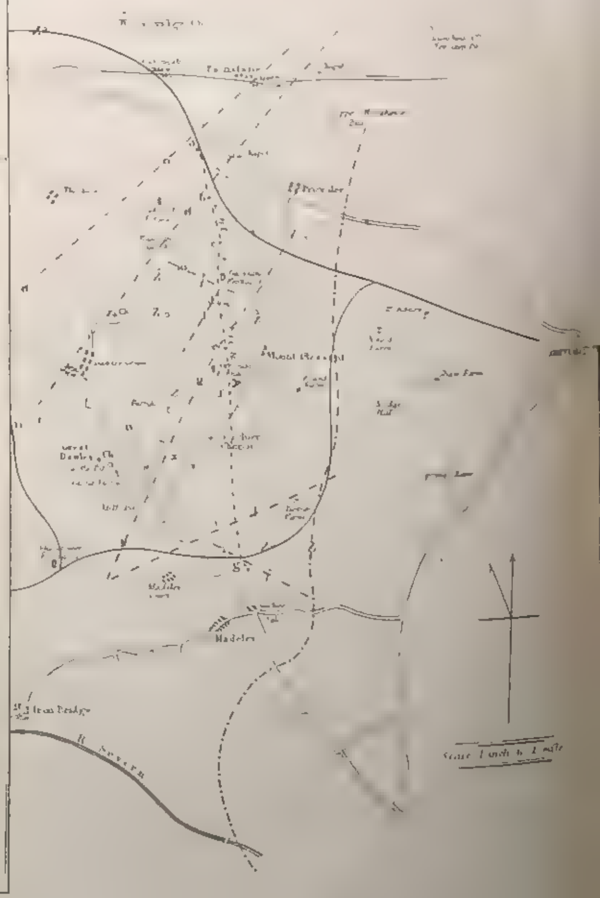
Found water.

At the railway-stations, only small supplies of water are required.

Sections, Actual & Hypothetical, of the Coalbrook-dale Coal-field. By Marcus W. T. Scott, Esq.r F.G.S., Mining Engineer; &c.



D. MAP OF A PART OF
THE COALBROOK-DALE COAL-FIELD,
shewing the Line of Section, the Direction of the Faults,
the Limits of the Coal beds, &c
(The finely dotted line indicates the boundary of the Malinslee and Stirchlee Royalties.)



2. *On the* "Symon Fault" *in the* Coalbrook-dale Coalfield. By Marcus W. T. Scott, Esq., F.G.S., Mining Surveyor, &c.

[Plate XIV.]

This paper comprises observations on a section through a part of the Shropshire Coalfield in nearly a straight line from north to south—commencing at the Greyhound Pit, near the Oakengates Tunnel of the Shrewsbury and Birmingham Railway, and terminating at John Anstice & Co.'s Halesfield Pits near Madeley; but it is more particularly intended to explain the nature of the "Great East Fault," or "Symon Fault," as it is locally called.

The district of which the section forms a part has been explored and brought before this Society in a paper "On the Geology of Coalbrook Dale," by Mr. Prestwich, published in the 'Transactions of the Society,' 2nd ser. vol. v. part 3, which fully treats also upon the fossil fauna and flora. My object is therefore not to enter into detail further than is necessary to explain the true nature of the "Symon fault," alluded to and described by Mr. Prestwich (*loc. cit.* p. 432) as far as the data then obtained would allow.

In May, 1843, I commenced my labours in the district, as check-viewer and surveyor for the owner of the Malinslee and Stirchlee Royalties, extending over an area of upwards of 1200 acres (within the dotted line on the Map D, Pl. XIV.). Since 1843 I have made half-yearly surveys and plans of the workings in the coals and ironstones, and have had opportunities of obtaining details necessary for my object.

The coals (where the whole of them occur) are, in a descending series, in the property referred to—

		ft.	in.		ft.	in.	
1. The Top Coal	from	4	0	to	4	6	thick.
2. The Half-yard Coal					1	6	
3. The Double Coal		5	0		6	0	
4. The Yard Coal		2	6		3	0	
5. The Big Flint Coal		3	0		4	6	
6. The Stinking Coal		3	0		4	0	
7. The Clunch Coal					2	0	
8. The Two-feet and Best (separated by fire-clay)					3	4	
9. The Randle and Clod Coal		4	0		5	0	
10. The Little Flint Coal		1	6		2	3	

the united thickness being somewhere about an average of 33 feet. The whole have been and are being worked more or less, with the exception of the Half-yard and Clunch Coal; the Half-yard Coal has been worked in a small freehold near Oakengates Tunnel on the Shrewsbury and Birmingham Railway, and there can be no doubt that ultimately, when the other and more profitable coals are exhausted, the two exceptions will be worked. In some parts of the royalty named, another coal, above the Top Coal, called the Fungus Coal, has been found, but not extending over a large area.

The Randle and Clod Coals have been the principal coals used in the blast-furnaces for making pig-iron—almost exclusively until within the last fifteen years, when the Little Flint Coal has been brought into use, and proves to be the best iron-making coal, used in a raw state,—producing, as I am informed, more iron per furnace per week than the Randle and Clod Coals from equal weights of materials. The other coals are mostly used for domestic, malting, and mill and forge purposes; but the Two-feet and Best, Big Flint and Yard Coal are now used partly in the furnaces in the shape of coke. The Stinking Coal (containing a great deal of sulphur, as its name implies) is principally used by the workmen, for brick-burning, and to a great extent at the blast-engine, rolling-mill-engine and other engines for the boiler-fires.

The ironstones of a workable nature, *per se*, are, in a descending series,—

1. Blue-flat } both lying between the Yard and Big Flint Coals.
2. White-flat }
3. Pennystone, lying immediately above the Stinking Coal.

Above the Top Coal lies the Ballstone (ironstone) Clod, and above the Yard Coal lies the Yellowstone (ironstone) Clod; they are worked or got as far as possible, when the coals are got from below them.

There are other chance ironstones found in the rocks and clods associated with some of the coals, but it is not necessary to notice them here. The object in detailing the coals and stones, so far, is because they bear upon the subject more immediately to be brought under notice.

When I first visited the locality (May 1843) the Randle and Clod Coals were being worked at a point near Mount Pleasant (on Map D), one mile south-east of Malinslee Hall; and on my next visit (Sept. 1843) the workings at that point had been given up, having been, as stated, *cut off by the Symon fault*; but I was subsequently informed by the bailiff who superintended the workings in that part of the field "that there was good coal left." The real cause of stopping the workings there was, as far as I have been able to learn, the approach to other property, and the Randle Coal being partly denuded by the *Symon fault*, and the great distance (in the Shropshire Coalfield then considered so) from the shafts. Since 1843 there have been no workings in the Randle and Clod Coals (the lowest workable coal but one) near the line of the so-called "Symon fault." In March 1845 I surveyed the workings in the Top Coal (the highest workable coal) near Malinslee Hall, up to the *Symon fault* and adjoining the great slip-fault, known as the "Lightmoor fault." On approaching the said *Symon fault*, the coal becomes interspersed with vertical fissures filled with white marl, from an inch up to nine inches or more in width; then the marl becomes gradually and completely mixed up with the coal until the coal becomes finally tailed out (something as shown in the sketch on A* *s*, Pl. XIV.).

Finding the Top Coal cut off at such a great distance from the point where the Randle and Clod Coal is stated to have been cut off (nearly a mile to the south-east), and the vertical depth from the top of the Top Coal to the bottom of the Clod Coal being 150 feet, I concluded that the *Symon fault* was a gradually denuded surface of the coal-seams and intervening strata, assuming that the coal-seams were originally deposited in a horizontal position or nearly so (this was before I had seen Mr. Prestwich's paper and sections).

To show the matter more clearly to myself, I obtained from time to time (through the kindness of the bailiff who had superintended the sinking of several of the pits in the Malinslee and Stirchlee property) the detail of the strata sunk through in five of these pits (*b, c, d, e, & f* on the section and map), being nearly in a straight line, nearly true north and south. I constructed the Section A, having previously ascertained, by levelling, the relative heights of the several pit-mouths above the top-water in the Shrewsbury Canal at the entrance to the Stirchlee Tunnel (the canal is now converted into a railway), allowing for the height of the pit-mounds as near as I could.

The main faults (Section A) are shown from their generally known throw or vertical displacement and the depths of the pits combined (there are a great many minor faults up and down, which are not shown on the section); from the depths of the pits the "dip" or inclination of the strata is also derived.

In 1856 having occasion to report on some property near Madeley, and immediately adjoining the Stirchlee Royalty on the south, I obtained a detail of the strata sunk through at Halesfield Pits, near Madeley, which pits happened to be, according to the Ordnance-map, nearly on the same straight line (continued from *e* through *f*). The Halesfield Pit is marked *g* on the section and map, and, from the information I received at the time, I constructed that part of the section northwards to the Limestone-fault (*j* on section and map). Between the Limestone-fault and a little south of pit *f* is at present unexplored; but should the Limestone-fault have the upthrow northwards of 70 yards, as I have been informed, there must be another downthrow fault southwards somewhere in the blank or unexplored part. The Section A shows three main faults, which run nearly parallel to each other from south-west to north-east (as shown on Map D). The *first*, in Stirchlee Royalty, a little north or left of pit *e*, has an upthrow north of 50 yards; the *second*, a little to the left or north of pit *b* (the Lightmoor fault), has an upthrow north of 130 yards. In 1858, having to report on the minerals under the Oakengates Tunnel of the Shrewsbury and Birmingham Railway, I obtained the depths (to the coals only) from the surface, and the level of the pit above the canal-water, at a pit close upon the tunnel, called the Greyhound Pit, which according to the Ordnance-map is on a straight line north with the pits *c* and *b* in Malinslee Royalty.

The position of the Greyhound Pit is marked *a* on the Section A and Map D. A little to the north of the pit *a* is the third main fault, having an upthrow north of 30 yards; I show these coals with a less dip than the other parts of the section, but without any very positive data to determine the same. The fault near to pit *g* (*i* on Map D and Sections A & B) is a cross fault running from north-west to south-east, and has a downthrow north of 30 yards; the

Limestone-fault runs nearly due east, and has an upthrow north (as stated) of 70 yards. The other faults shown on Section A are mostly cross faults, running between the main faults; that at *l* on Section A and Map D having a rise N.W. of 11 yards, and *m* a downthrow north of 30 yards. The Section A is on a scale of 12 chains, or 792 feet to an inch horizontal, and 200 feet to an inch vertical.

There is, except in some few instances, scarcely any perceptible dip of the strata, as in working the minerals the horse-roads are driven in all directions; still the general dip appears to be from south-west to north-east. The Section A, by the depths of the pits, shows the dip from south to north at an angle of 2° 28′, or 1 in 25.

Looking at the Section A, it conveys but a very indistinct notion of the denudation or *Symon fault*, in consequence of the dip and the slip-faults. It therefore occurred to me that it would not be an unwarrantable geological liberty to assume that the coal-beds were originally deposited in a horizontal position, or nearly so; and that the true nature of the denudation or *Symon fault* might be more clearly shown by plotting the several sinkings upwards, taking the Little Flint or lowest workable coal as a base. Such is shown in Section B. The dark line at the top corresponds with the present surface-line on Section A (without reference to the dip of the strata on Section A). That part of the Section B, from point E, about 180 yards south of pit *f*, to pit *b*, on the north, shows the denudation (or cutting off of the coals and several strata above) up to what is locally called the "Calamincar," as actually proved by the sinkings,—the Top Coal being cut off at a point about 2100 yards north of pit *f*, the Double Coal (28 feet below the Top Coal) at about 1100 yards, the Yard Coal (8 feet below the Double Coal) at about 770 yards, the Big Flint Coal (25 ft. 9 in. below the Yard Coal) at about 440 yards—all north of pit *f*,—and the Stinking Coal (47 feet below the Big Flint Coal) close to pit *f*; from point F, Section B, to pit *g* may also be taken as proved. Between E and F, a distance of about 1300 yards is assumed (on Section B), and I think may be fairly so, when we take into consideration the identity of the strata at pits *f* and *g*. The present depths of the pits to the Little Flint Coal are as follows (some of the pits are not sunk to the Little Flint Coal, but the distance below the Clod Coal is pretty uniform):—at pit *b*, 751 ft. 9 in., in which the Top Coal and all the coals below are found; at pit *c*, 669 ft. 1 in., and pit *d*, 492 ft. 9 in.; in these two pits the Top Coal is absent, but all the other coals are in. Pit *e* is 593 ft. 1 in.; but here the Top, Half-yard, Double, and Yard Coals are absent, the others below being in. Pit *f* is 489 ft., but the Top, Half-yard, Double, Yard, Big Flint, and Stinking Coals are absent. Pit *g* is 836 ft. 10 in., with all the coals in, but more divided than at pit *b*; the two detached sections at C, 60 feet to an inch, show from the top of the Top Coal to the bottom of the Little Flint Coal; that on the left (*p*) being at pit *b*, and that on the right (*q*) at pit *g*; in the space (*r*) between are shown the connexion and subdivision of the strata: pits *b* and *g* are 4484 yards apart. The top of the Top Coal at pit *g* is at present somewhere about 147 ft. 6 in. below the top of the same coal at pit *b*. From the top of the Top Coal to the bottom of the Yard Coal (including four coals, 14 ft. 9 in. thick) at pit *b* is 40 ft. 9 in., whilst at pit *g* it is only 11 ft. 7 in., and the four coals are only 9 ft. 4 in. thick; the Half-yard, Double and Yard Coals being respectively 1 ft. 6 in., 1 ft. 8 in., and 1 ft. 8 in., which at pit *b* are 1 ft. 6 in., 6 ft., and 2 ft. 9 in. From the bottom of the Yard Coal to the bottom of the Big Flint at pit *b* is 25 ft. 9 in., whilst at pit *g* the distance is 89 ft.; there is actually no Big Flint Coal in pit *g*, but it is found close to on the north of the pit; there is also no Blue Flat nor White Flat Ironstone of consequence at pit *g*. From the bottom of the Big Flint Coal to the bottom of the Stinking Coal (4 feet thick) at pit *b* is 47 ft., the Pennystone Clod above the Stinking Coal being 20 feet thick. At pit *g* the distance between the two coals is only 19 ft. 6 in.,—the Stinking Coal being only 1 foot, and the Pennystone Clod 5 feet thick. From the bottom of the Stinking Coal to the top of the Clunch Coal at pit *b* is 27 feet, and at pit *g* it is 18 ft. 6 in., the space between being called the Clunches. From the top of the Clunch Coal to the bottom of the Clod Coal at pit *b* (five coals, 9 ft. 6 in. thick) is 13 ft. 6 in., and at pit *g* (eight coals, 12 ft. 5 in. thick) it is 39 ft.. From the bottom of the Clod Coal at pit *g*, to the bottom of the Little Flint Coal (1 ft. 6 in. thick) is 13 ft. 6 in., and at pit *g* it is 21 ft. 6 in., the Little Flint Coal being 2 ft. 3 in. thick. The total depth from the top of the Top Coal to the bottom of the Little Flint Coal at pit *b* is 167 ft. 6 in., and at pit *g* 198 ft. 7 in., or 31 ft. 1 in. more. The total thickness of coal at pit *b* is 32 ft. 9 in., of which 29 ft. 3 in. is worked at present, and the remainder will no doubt be worked at some future period. At pit *g*, the united thickness of coal is 29 ft. 9 in., of which 19 ft. 7 in. may be taken as workable, the other seams being too thin to be ever worked profitably.

The first stratum or measure above the Top Coal, which is persistent throughout the several sinkings, is locally called the "Calamincar" (No. 12 on Sections A & B). It is found in all the pits (in pit *d* merely a trace), and is of a variable thickness from 1 to 15½ feet; it is of a mixed red, blue, and yellow colour. At pit Z' it is 33 feet thick, pit Z'' 48 ft. thick; pit Z''' 22 ft., and pit Z'''' 16 ft. 6 in. From the bottom of the Calamincar to the top of the Top Coal at pit *b* is 92 ft. 6 in., and at pit *g* 59 ft. At pit *f* the Calamincar rests upon the flint rock, which is 62 feet below the Top Coal at pit *b*, and 94 ft. 9 in. at pit *g* (difference 32 ft. 9 in.); from the bottom of the Calamincar to the bottom of the Little Flint Coal at pit *b* is 260 ft., and at pit *g* 256 ft. 11 in. (difference 3 ft. 1 in.) The strata between the Calamincar and Top Coal at pit *b* gradually diminish southwards till at pit *e* none of them are found; neither are any of the coals and intervening strata from the Top Coal to the bottom of the Yard Coal in that pit, the Calamincar resting upon the top of the Blue-flat Ironstone-clod. At pit *d* the Half-yard Coal is represented by "slummy or slaty measures" 2 ft. 6 in. thick, the Top Coal being denuded or cut off by the *Symon fault* between pits *b* and *c*, and the Double and Yard Coals between the pits *d* and *e*. It would appear that a surface at one time existed, rising from the top of the Double Coal Rock (which occupies the space between the Double Coal and Half-yard Coal, above) at pit *d* to the top of the Ballstone Clod (above the Top Coal) at pit *b* at an inclination of about 1 in 50, or an angle of 1° 15′, and that the strata from the Ballstone Clod up to the Calamincar were subsequently deposited on that surface, and which were again partially washed away down to the Flint-rock at pit *f*, on which the Calamincar rests, the Flint-rock resting upon the Upper Clunches—the Stinking Coal and Pennystone-measures having been denuded previous to the deposition of the Flint-rock, as shown by the small depression in the section. Above the Calamincar comes the Rough Rock, very uneven in the bottom and irregular in thickness (15 to 51 ft.; average 28 ft. 9 in.); and in many places it is a complete conglomerate. Above the Rough Rock comes the "Brickman's Measure," brickmaking-clay 6 to 15 ft. thick. Immediately above the Brickman's Measure there are two clods or clunches, together from 5 to 15 feet thick, including two coals in some of the sinkings, 1 foot thick each. Above these clunches come "strong binds," and rock of variable thickness (72 ft. at pit *b*, 80 ft. at pit *c*, 78 ft. 6 in. at pit *d*, 67 ft. 6 in. at pit *e*, 29 ft. at pit *f*, and 97 ft. 4 in. at pit *g*) up to two coals which occur in all the sinkings, 1 foot thick, with fire-clay between and clod below, from 3 ft. 6 in. to 8 ft. 9 in. thick together. Immediately above these small coals is the Stinking Rock, varying from 49 ft. to 61 ft. 6 in. in thickness—average 52 ft. 6 in.; it is at this rock that the water is coffered or tubbed back throughout the district. Above the Stinking Rock there are clunches and rock-binds from 48 ft. to 84 ft. 6 in. thick—average 69 ft. At pit *g* two coals occur in the same, 6 inches and 3 inches thick respectively. In some of the sinkings these clunches are divided into many parts—in others they are not divided. Above these clunches comes a rock, called the Thick Rock. It is described as "rock" in all the sinkings, except pit *c*, where there is 20 feet of "dark sticky shades and clod;" it is 51 feet at pit *b*, and gradually thickens up to 90 ft. 4 in. at pit *g*—average 67 ft. 8 in. Above the Thick Rock come clunches and clods 45–81 feet thick—average, 58 ft. 3 inches; at pit *g*, 18 ft. above the Thick Rock there is a coal 8 inches thick. Next above these clunches comes the Top Rock, described as rock in all the sinkings where it occurs, but pit *b*; it is 27 ft. at pit *g*, 24 ft. at pit *f*, 27 ft. at pit *e*; it is not in pit *d*; it is 57 ft. thick at pit *c*, and at pit *b* 24 ft. of rock, but 57 feet, including 33 ft. of red clunch, white clod, and brown clunch. It is quite possible that close attention has not been paid by the sinkers to the divisions in pit *c*, and that a stratum of clod and clunches exists in that pit not taken notice of, seeing the uniformity of the rock itself in pits *b*, *e*, *f*, and *g*. Above the Top Rock at pit *g* there is 3 ft. of blue clunch, and above that 135 feet of red clay; at pit *f* there is 15 ft. of clay and earth; at pit *e* 49 ft. of blue and red clay above the Top Rock, and at pit *b* 33 feet of blue and red clod and clunches with a chance-coal 1 ft. thick. I have not been able to get any specimens from the strata above the Calamincar to determine the era, &c.*; but from the appearance of the rocks exposed to view, and the many coals interspersed, they appear to me to belong to the true coal-measures; on the Geological Survey Map they are coloured as belonging to the coal-measures. The Sections A and B are on too small a vertical scale to show at the several pits in detail the several divisions as given by the sinkers. At pit *b*, from the surface to the bottom of the Little Flint Coal there are 68 divisions, and at pit *g* 89 divisions.

The table on pp. 464, 465 shows the depths from the present surface to, and the thickness of, the main measures (the clunches not in detail) at pits *b*, *c*, *d*, *e*, *f*, and *g*.

From a general review of all the circumstances, there can be no doubt that the *Great Symon fault*, as shown by Section B, and proved by actual facts to the north of pit *f*, indicates the existence of an old valley or estuary of denudation of the coal- and ironstone-measures, in which subsequently other strata of the coal-measures were deposited; and that these were partially washed away again. The deepest part of this old valley appears to me to be somewhere about pit *f*, where the coal-measures have been washed away as deep as the Upper Clunches below the Stinking Coal, and where the Flint-rock rests immediately upon the Upper Clunches, which occur in all the sinkings, and varies from 13 to 27 feet thick—the average being 21 ft. 7 in. The information that I have been able to obtain as regards the Randle and Clod Coal south of pit *f* leads me to the conclusion that the *Symon fault* has never entirely cut off that coal and the three coals immediately above; and that the working of the Randle and Clod Coal in a southward direction was given up partly in consequence of the coal being a little deteriorated by the denudation, partly from the inflammable gas being more abundant, and from there being plenty of coal northwards of pit *f* to work, and less faulty: besides, to work further south would require more sinkings, whilst there were plenty of pits to obtain the said coal (then considered the best furnace-coal) to supply the furnaces which were at that time at the extreme north end of the estate with which I am more particularly acquainted; and as we find the whole of the coals at pit *g* but slightly altered as to their relative position and thickness, with the Calamincar and the several rocks and clods above (which there can be no difficulty in identifying with the strata sunk through at the other pits), there is every reason to suppose that the coals come in again southwards of pit *f*, something in the manner represented in Section B, but of course altered by the dislocations and the dip. Assuming such to be the case, there is every probability of an area of coal and ironstone being found (at least it is to be hoped so) at a workable depth in the district, and possibly underneath the Lower New Red Sandstone, where hitherto none was expected by the practical workers. I express this opinion from the

* Mr. Prestwich has treated of the strata and their fossils fully in his memoir above cited, pp. 444–446, &c.

	Present depths from the present surface to the top of each main rock and coal.						Thickness of each measure.					
	No. *b* pit. Pudley Hill	No. *c* pit. Lawn.	No. *d* pit. Wharf.	No. *e* pit. Cuxeys coal	No. *f* pit. Grange.	No. *g* pit. Halesfield.	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Sundry clods	……	……	……	……	……	……	48 9	3 0	……	54 0	15 0	138 0
Top rock	48 9	3 0	……	54 0	15 0	138 0	24 0	57 0	……	27 0	24 0	27 0
Sundry clods	……	……	……	……	……	……	115 0	53 0	……	48 0	45 0	64 1
THICK ROCK	187 9	113 3	……	129 0	84 0	229 1	51 0	62 0	62 3	69 0	72 0	90 4
Blue clod, &c.	……	……	……	……	……	……	48 0	80 0	84 6	73 6	78 0	57 7
STINKING ROCK, 3 small coals below	286 9	255 3	146 9	271 6	234 0	377 0	49 0	44 0	43 6	61 6	60 0	49 6
Strong binds	……	……	……	……	……	……	7 0	4 0	8 9	8 6	3 6	6 11
White rock and binds	342 9	303 3	199 0	341 6	297 6	433 5	72 0	80 0	78 6	67 6	29 0	97 4
Potato-but and red clod	……	……	……	……	……	……	10 0	8 6	15 0	5 0	5 0	6 8
Brickman's measure	424 9	391 9	292 6	414 0	331 6	537 5	6 0	6 0	15 0	15 0	15 0	12 0
Rough rock	430 9	397 9	307 6	429 0	346 6	549 5	51 0	20 0	17 6	27 0	42 0	15 0
CALAMINCAR	481 9	417 9	325 0	456 0	388 6	564 5	10 0	3 0	trace.	15 0	15 0	15 6
Rock binds and clod	……	……	……	……	……	……	20 0	24 0	……	……	……	……
Dark rock	511 9	444 9	……	……	……	579 11	41 0	39 0	……	……	……	8 0
Clods, bass and ballstone	……	……	……	……	……	……	31 6	20 0	……	……	……	50 4
TOP COAL	584 3	……	……	……	……	638 3	4 6	……	……	……	……	5 4
Bass and slums	……	……	……	……	……	……	14 6	24 0	26 6	……	……	0 4
HALF-YARD COAL	603 3	527 9	……	……	……	643 11	1 6	1 6	……	……	……	1 6
Double-coal rock	604 9	529 3	351 6	……	……	……	6 0	6 0	4 6	……	……	0 3
DOUBLE-COAL	610 9	535 3	356 0	……	……	645 8	6 0	6 0	6 0	……	……	1 6
Pouncestone and yellow-stone clod	……	……	……	……	……	……	5 6	6 0	5 6	……	……	0 6

YARD COAL	622 3	547 3	367 6	......	......	647 8	2 9	3 0	3 0	......	......	1 8
Blue and white-flat clods	......	......	......	......	......	......	22 9	26 6	25 3	17 9	......	89 0
BIG FLINT COAL	647 9	576 9	395 9	488 9	......	738 4	3 0	5 0	4 6	4 6	......	trace.
Flint-rock	650 9	581 9	400 3	493 3	403 6	738 4	23 0	17 0	15 0	18 0	17 0	13 6
Pennystone clod	......	......	......	......	......	......	20 0	26 0	23 0	18 0	......	5 0
STINKING COAL	693 9	624 9	438 3	529 3	......	756 10	4 0	4 0	4 0	4 0	......	1 0
Upper clunches	......	......	......	......	......	......	27 0	13 0	20 0	24 0	27 0	18 6
CLUNCH COAL	724 9	641 9	462 3	557 3	447 6	776 4	2 0	2 0	2 0	2 0	2 0	Coal .. 2 3 Clunch .. 3 6 Coal .. 0 10 Fire-clay 3 6 10 1
Clunch and fire-clay	......	......	......	......	......	......	2 6	1 0	1 6	1 6	5 0	
TWO-FEET COAL	729 3	644 9	465 9	560 9	454 6	786 5	2 0	2 6	2 6	2 4	2 0	Coal ...... 1 6 Clunch .. 6 0 Coal ...... 0 10 Bass & binds 4 1 Coal....... 1 4 Clunch 8 0 21 9
Clunch	......	......	......	......	......	......	1 0	1 6	1 4	1 6	4 0	
BEST COAL	732 3	648 9	469 7	564 7	460 6	808 2	1 4	1 4	1 4	1 4	1 4	2 2
Bass and slum	......	......	......	......	......	......	0 6	0 6	0 2	0 6	0 4	1 0
RANDLE COAL	734 1	650 7	471 1	566 5	462 2	811 4	2 10	3 0	3 0	2 8	2 8	2 6
Parting	......	......	......	......	......	......	......	......	......	......	1 0	0 6
CLOD COAL	736 11	653 7	474 1	569 1	465 10	814 4	1 4	2 0	2 0	2 0	1 2	1 0
Clod	......	......	......	......	......	......	2 0	2 0	3 0	4 0	4 0	4 0
Hard sandstone	740 3	657 7	479 1	575 1	471 0	819 4	10 0	10 0	12 0	16 0	16 0	15 2
LITTLE FLINT COAL	750 3	667 7	491 1	591 1	487 0	834 6	1 6	1 6	1 8	2 0	2 0	2 4
Total depth	751 9	669 1	492 9	593 1	489 0	836 10	751 9	669 1	492 9	593 1	489 0	836 10

circumstances detailed above, and shall be glad if it should meet with the support of those gentlemen of the Society who have given more attention to geology than myself, and are consequently much more able to explain their views and advance hypotheses more in accordance with nature's laws: the subject is of vast importance, national and individual.

On the Map D I have attempted to lay down by dotted lines (t—y) the general line of denudation of the several coals, &c. on the north side of the old valley or estuary, as derived from my surveys and the sinkings in the Malinslee and Stirchlee Royalties, and from the sinkings in other fields. At the Castle Pits near Great Dawley Church, the Top and Half-yard Coals are absent, the Double and all the other coals, &c. being in; at the Mill Pit, a little further to the south, the Top, Half-yard, Double, Yard, and Big Flint Coals are absent, the Pennystone and all the measures below being in.

About half a mile north-west of pit *b* a pit has been lately sunk, 30 yards below the Little Flint Coal, of which the following is the detail, measured by myself Oct. 5, 1857.

				Total depth below L. F.		
	yds.	ft.	in.	yds.	ft.	in.
1. Rock	10	2	6	10	2	6
2. Parting	0	0	6	11	0	0
3. Rock and binds	6	2	0	17	2	0
4. Rock	2	1	0	20	0	0
5. Ironstone 8″ to 10″	0	0	9	20	0	9
6. Clod	0	1	10	20	2	7
7. Ironstone 4″ to 6″	0	0	5	21	0	0
8. Rock and binds	1	1	0	22	1	0
9. Hard Bastard Rock with rough pebbles. (Left off sinking.)	7	2	0	30	0	0

REFERENCE TO ILLUSTRATIONS IN PLATE XIV.

A. Section of the strata as they at present exist B. Section of the same strata as in A, plotted upwards from the Little Flint Coal as an assumed base	Horizontal scale, 12 chains = 1 inch: and vertical scale, 200 feet = 1 inch.
C. Enlarged comparative sections of coal-seams at pits *b* and *g*	Scale, 60 feet to an inch vertical.
D. Map showing the line of section, &c.	Scale 1 inch = a mile.

Sections A, B, and C.

a. The Greyhound pit near Oakengates Tunnel.
b. Pudley Hill Pit, Malinslee and Stirchlee Royalties.
c. Lawn Pit ,, ,,
d. Wharf Pit ,, ,,
e. Cook's (or Cuxey's) Wood Pit ,, ,,
f. Grange Pit ,, ,,
g. Halesfield Pits, near Madeley.

h. Level of top-water of the Shrewsbury Canal at entrance to Stirchlee Tunnel as it existed previous to being converted into a railway.
h'. Present surface-line.
i. Fault, downthrow north 30 yards.
j. Fault, said to have an upthrow north of 70 yards.
k. „ upthrow north of 50 yards.
l. „ „ „ 11 yards.
m. „ down-throw north of 30 yards.
n. „ upthrow north of 130 yards.
o. „ „ „ 30 yards.
p. Enlarged section from Top to Little Flint Coal at pit *b*.
q. „ „ „ at pit *g*.
r. Space between the two pits 4484 yards.
A* *s*. Sketch showing the Top Coal in connection with the Symon Fault.

Map D.
t. Line of denudation of the Top Coal.
u. „ „ Double Coal.
v. „ „ Yard Coal.
w. „ „ Big Flint Coal.
x. „ „ Stinking Coal.
y. „ partial denudation of the Randle Coal.
Z. Western limit of Lower New Red Sandstone—Geological Survey.
Z'. Forge Meadow Pit—Calamincar 33 ft. thick.
Z''. Wood Pits „ 48 „
Z'''. Spout Pits „ 22 „
Z'''' Randley Pit „ 16 ft. 6 in.
*Z*5. Railroads.

Sections A & B.
1'. Red clay.
1. Blue and red clod and clunches with a coal at pit *b*.
2. Top rock.
3. Clunches and clods.
4. Thick rock.
5. Clunches and rock-binds.
6. Stinking rock.
7. Fire-clay clod and coals.
8. Stony binds and rock.
9. Clunches, with coals.
10. Brickman's measure.
11. Rough rock.
12. CALAMINCAR (the first persistent stratum above the principal coal-seams).
13. Rock-binds and clod.
14. Ballstone (ironstone) clod.
15. Top coal.
16. Bass and slaty measure.
17. Half-yard coal.
18. Double coal rock.
19. DOUBLE COAL.
20. Yellowstone (ironstone) clod.
21. YARD COAL.
22. Blue-flat ironstone clod.
23. Pitch of basses (rock at pit *g*).
24. White-flat ironstone clod.
25. BIG FLINT COAL.
26. Flint-rock.
27. Pennystone (ironstone) clod.
28. STINKING COAL.
29. Clunches (fire-clay).
30. CLUNCH COAL.
30'. TWO-FEET COAL.
30''. BEST COAL.
30'''. RANDLE and CLOD COAL.
31. Clunch and hard rock.
32. LITTLE FLINT COAL.

MAY 8, 1861.

Robert Mills, Esq., F.S.A., Rochdale; Edmund William Ashbee, Esq., 14 Rutland Street, Mornington Crescent; and Captain Willoughby Osborn, C.B., Madras Army, were elected Fellows.

The following communications were read:—

1. *On* Two Bone-caverns *in the* Montagne du Ker *at* Massat, *in the Department of the* Ariège*. By M. Alfred Fontan.

(Communicated by M. Lartet, Foreign Memb. Geol. Soc.)

[Abstract.]

The Valley of Massat, situated near the centre of the Pyrenees, opens to the west between two lofty mountains, which, at first approaching each other, spread out and diverge as they extend on the south-east towards the mountain-range of which they are the ramifications, so that in this direction the valley has no outlet. It thus forms an elongated basin, of a triangular form, the base of which extends along the side of one of the great spurs of the Pyrenees (see fig. 1), whilst the apex forms a narrow and winding gorge which affords the only outlet for the waters of the valley.

A short distance above the spot where the basin commences, namely on the western side, near the apex of the triangle, a high mountain of limestone rises up, which, advancing abruptly into the valley, forms an elevated promontory, against which the torrents or diluvial waters, which appear to have inundated this region at one or several remote periods, must have rushed. It stretches out almost at a right angle from the southern side of the basin; and, exactly where it extends furthest into the basin, its crest forms a mound or hillock, the summit of which is considerably more elevated than all the surrounding heights. The whole of this mountain, which has been violently disturbed and disjointed, is bare, and is filled with fissures, crevices, and deep hollows or grottos, the principal galleries of which extend from N.N.W. to S.S.E., parallel to the longitudinal axis of the valley.

Amongst these caves two are remarkable on account of their extent.

One of them, situated near the summit of the mount, at an elevation of about 100 metres (330 feet) above the bed of the valley, is approached by a spacious vestibule, or outer chamber, with two large and lofty circular entrances, one of which faces the north, the other N.N.W. (see figs. 1 & 2). The soil of the outer chamber, which, like the rest, was devoid of all stalagmitic concretions, was smooth and horizontal, rising above the sill of the entrance. With the exception of a small portion near the N.N.W. entrance, where a few fragments of pottery were found, mixed with cinders and coal, it presented the appearance of an abandoned river-bed. A sandy loam sprinkled with gravel or small rolled pebbles occupied the centre; whilst at the edges against the wall of rock, larger but similarly rolled pebbles appeared to have been thrown up by the eddying or movement of the water. These deposits continued in the same way for a distance of a hundred metres along the principal gallery, only diminishing in thickness as they extended further inwards, and entirely ceasing at the further end.

This arrangement, combined with the presence, at such a considerable elevation, of rolled pebbles, most of which were different from

* A brief notice of this subject is given in the Quart. Journ. Geol. Soc. vol. xvi. p. 491.

Fig. 1.—*Plan of the Valley of Massat, near Tarascon, in Languedoc; showing the position of the two Caverns in the Montagne du Ker.*

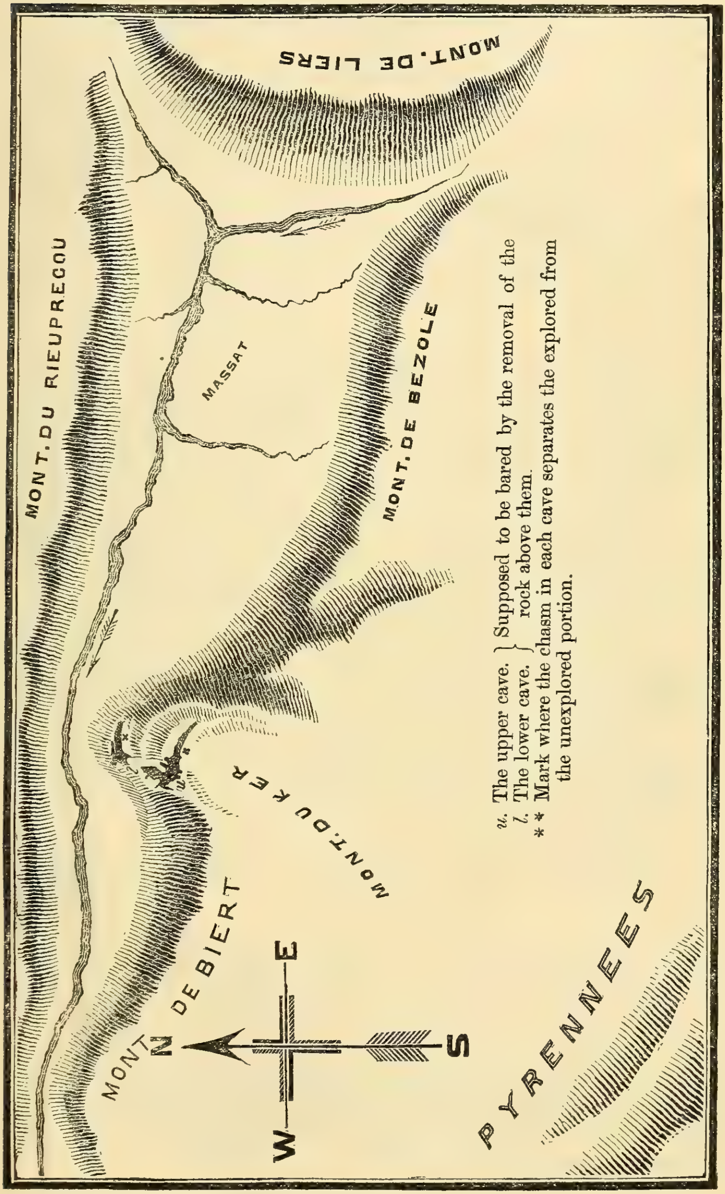
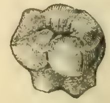


Fig. 2.—*View (from the north-west) of the Montagne du Ker, showing the entrances of the Upper and the Lower Caverns.*

the rocks of which the mountain consists, appeared to the author as solely attributable to those diluvial cataclysms which geology points to as having occurred at several periods anterior to historical tradition. In order to understand these facts, he determined to study the nature of the deposits; for which purpose he caused a deep trench to be dug in the soil near the northern opening, and extended it to the lateral walls. The result of this first attempt was the discovery of a large quantity of bones of *Carnivora*, *Ruminantia*, and *Rodentia*, amongst which were most abundant the great Cave-bear described by Cuvier, a large species of *Hyæna* (*H. spelæa*), and a large *Felis* (tiger or lion), all mixed together, rubbed, and broken, giving evidence of a distant transport, or at least of a violent displacement. Besides the cinders and charcoal at the surface (with which were associated fragments of pottery, an iron poignard, and two Roman coins), another bed of cinders and charcoal was found at a depth of more than three feet in the ossiferous loam, and here M. Fontan found a bone arrow-head and two human teeth (fig. 3); the latter were at a distance of 5 or 6 metres one from the other.

Fig. 3.—*One of the two Human Teeth found in the Upper Cavern, Montagne du Ker, Languedoc.*



The second or lower cavern is situated at the foot of the mountain, close to the road, at an approximative height of 20 metres above

Fig. 4.—*Bone Arrow-head from the Lower Cavern, Montagne du Ker, Languedoc.*

the bed of the river (see figs. 1 & 2). Its only opening (which, like those of the upper cavern, is contrary to the present direction of the water) leads into a tolerably spacious chamber, the ground of which consists of a blackish earth and of large rolled pebbles (some of them granitic), amongst which are scattered, in the greatest confusion, fragments of bones belonging to animals either of extinct species or of such as have for the most part long since ceased to inhabit these regions. They belong principally to Deer (*Cervus elaphus*), Antelopes, and Aurochs; and there were a few remains of feline *Carnivora* (apparently a Lynx). Amongst these were found worked flints and numerous utensils of bone (deer's bone chiefly), such as bodkins and arrows; the latter were the most numerous, and are carved with oblique grooves, probably for poison (see fig. 4). Some of the bones bear marks of incisions made by sharp instruments in flaying or cutting up the carcases.

In each cavern a chasm crosses the gallery and terminates the deposits; in the upper cave at 100 metres, in the lower one at about 7 metres from the entrance.

M. Fontan argues that rain-water could not have introduced nor arranged the deposits within these caverns; and that the position of the entrances of the caves (facing the N.W.), and the presence of the fissures which cross the caves, preclude the idea of the waters of any torrent from the Pyrenees leaving these deposits on the floors of the caverns. He observes, "From all these phenomena, the most striking feature in my opinion is this, namely, that the Valley of Massat appears to have been at one and perhaps at several periods the theatre of a vast inundation coming from the N.N.W. or West, in the opposite direction to that of the present course of the waters of this region." . . . . . . "The fact of a flood produced by torrents capable of filling up this valley is not a simple accidental occurrence to be explained by causes purely local. If it existed, similar effects must have been produced in all the neighbouring regions, and must even have extended to a great distance. It would have been a true deluge, destroying everything on its passage; and, as history is silent on the subject, we cannot believe it to have been of recent occurrence. If then the entombment of human remains under the upper bed of cinders and charcoal is to be attributed to this cause, the appearance of man in these regions would date from a very distant period."

"In conclusion (says the author) we may deduce from these facts,—1st, That a diluvial current penetrated into the Valley of Massat, coming from N.N.W. or West towards the S.S.E. or East. 2ndly, That this current did not continue for a long time. 3rdly, That Man and all the other animals the remains of which are buried in these caves existed in the valley before this cataclysm. 4thly, That the greater part of these animals inhabited these caves; from whence we must suppose that Man was not the contemporary of all of them. In fact we cannot admit that he lived in this narrow valley at the same time as the Lions, the Hyænas, and the Bears; we cannot even admit that all these animals existed there at the same time, either because they do not usually inhabit the same climate, or because their habits are incompatible. Each kind inhabited the cavern successively; and Man was probably the last. When he appeared there was probably nothing remaining but the Deer and other Ruminants, which would satisfactorily explain why the tools which have been found were made exclusively from the bones of these animals."

List of objects found in the two Caverns above-mentioned, according to M. LARTET.

Upper Cavern.	Tiger or Lion	Fragment of a lower jaw, and 3 or 4 detached teeth.
	Lynx	Half of a lower jaw.
	Hyæna (*H. spelæa*)	Several teeth and ungual phalanges.
	Bear (*Ursus spelæus*, Cuv.)	A great number of teeth and various bones.
	Badger	Three fragments of the jaw and a few detached teeth. (These remains appear to be more recent than those of other species.)
	Wild Boar	Five or six teeth.
	Sheep or Antelope	Two teeth.
	Roebuck	Half of a lower jaw.
	Dog, Fox, or Wolf	Incisor and molar teeth.
	Rodent (*Mus sylvaticus*)	Several teeth and fragments of a jaw.
	Water-rat	Half of a lower jaw.
	Hedgehog (*Erinaceus europæus*)	Half of a lower jaw.
	Two human teeth and an arrow of bone. (This arrow has been lost, and M. Lartet has never seen it, so that it is impossible to say whether it was made of the bone of a Ruminant like those found in the lower cavern (fig. 4), or of the bone of a Carnivorous animal.)	
	Cinders and Charcoal.	
Lower Cavern.	Bear (probably the existing Bear of the Pyrenees)	A fragment of a lower jaw.
	Lynx	Lower canine tooth.
	Cat (*Felis catus*)	Two or three fragments.
	Deer (*Cervus elaphus*)	Numerous antlers, sawn and carved bones, all of which have been intentionally broken, many jaws, and a few scattered teeth.
	Ox (*Bison priscus*)	Half of a lower jaw, and horns.
	Goat or Ibex	Many remains.
	Sheep or Lesser Moufflon	A few bones and fragments of jaws.
	Chamois (*Antilope rupicapra*)	Maxillary bones, jaws, and bones; and a horn showing marks that the animal was skinned in a fresh state.
	Birds (Magpie and Jay)	A few rare fragments.
	Wild Boar	A molar and a few fragments.

Lower Cavern.

Remains of Human Industry.

Several bones of Ruminants, chiefly of *Cervus*, worked up as arrows and carved with spiral grooves, needles, coins, harpoons, bodkins, &c. Two vertebræ of a large Fish resembling those of the Cod-fish, and fragments of chipped flints. There were also some specimens of white flint chipped into the form resembling what are called "knives."

Note by M. Lartet, For. Mem. G. S.

I regret that M. Fontan has not inserted here, as in one of his former communications, any notice of the *Megaceros Hibernicus* *: it is true that when I recently made some excavations in the *lower* cavern of Massat, I did not find the slightest fragment which appeared to belong to this large extinct Ruminant; but, as there was found amongst the objects formerly collected by M. Fontan, a fragment of a palmated antler referable to the *Megaceros Hibernicus*, he would, perhaps, have been of opinion that it should have appeared in one of these lists. The existence of remains of this fossil Deer has been proved in other spots at the foot of the Pyrenees, so that there would be nothing improbable in its occurrence in one or the other of the caves of Massat. With regard to the *Cervus pseudovirginianus* (M. de Serres) mentioned in the former lists †, I have myself suggested its omission, because the distinctive characters which led me to adopt this species do not now appear to me to be sufficiently made out, and they depend, if I am not mistaken, on mere varieties of form attributable to a difference of age or sex.

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2. *Notes on some* Further Discoveries *of* Flint Implements *in Beds of* Post-pliocene Gravel *and* Clay; *with a few Suggestions for Search elsewhere.* By Joseph Prestwich, Esq., F.R.S., Treas.G.S.

[This paper was printed in the August Number of the Quarterly Journal (p. 362) by permission of the Council.]

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3. *On the* Corbicula (*or* Cyrena) fluminalis *geologically considered.* By J. Gwyn Jeffreys, Esq., F.R.S., F.G.S.

[Abridged.]

Mr. Jeffreys having stated that he had identified the species of *Corbicula* found by Mr. Prestwich in a raised sea-beach at Kelsey Hill ‡, in Yorkshire, with that of the Grays deposit, as well as with the recent species from the Euphrates and the Nile, proceeded to

* See Quart. Journ. Geol. Soc. vol. xvi. p. 492.

† *Loc. cit.*

‡ See above, page 446.

give a sketch of the history and synonymy of the species under consideration; and he added some remarks which follow.

In 1774, O. F. Müller (the celebrated Danish naturalist) described, in his 'Verm. Terr. et Fluv. Hist.' p. 205, a shell from the River Euphrates, under the name of *Tellina fluminalis*. His description exactly corresponds with the triangular form of the fossil shells from Kelsey Hill and Grays. In 1811, Megerle v. Mühlfeldt founded on this and other allied species the genus *Corbicula*; which name is now adopted by conchologists. In 1818, Lamarck proposed for the same species the generic name of *Cyrena*; apparently not being aware of Mühlfeldt's publication.

Many recent species of *Corbicula* (or *Cyrena*) have been described by Lamarck, Férussac, and others. The most *westerly* station given by any of the conchologists is the Nile. Goldfuss, Nyst, Galeotti, Philippi, Searles Wood, and others have also described many Tertiary species of *Corbicula* (or *Cyrena*) under other names. The most *easterly* locality given by any of the palæontologists is Cefali, near Catania. It is, however, highly probable that most of these species, whether recent or fossil, ought to be united.

The tendency to variation in freshwater shells is very much greater than in their marine analogues. Almost every river, or piece of standing water, yields a different form of *Anodonta cygnea*, or of *Limnæus pereger*; and the number of "species" that have been fabricated out of these forms is astonishing.

The range of locality or station among freshwater shells is equally great, and far exceeds that of marine shells. A species of *Physa* which inhabits the West Indies, and called *Physa Jamaicensis*, cannot be distinguished from a variety of *Physa acuta*, a well-known European species; while species of *Limnæus*, *Pisidium*, and other freshwater shells from the East Indies, and even from Siam, so closely resemble in every respect those of Western Europe, that it is only by calling them "representative" species that any pretence for distinction can be maintained*.

Taking, therefore, into consideration the extreme variability and ubiquity of freshwater shells, it is not surprising that the *Corbicula fluminalis* should have at one period inhabited that part of the European continent which now constitutes Great Britain as well as Sicily and the valleys of the Euphrates and Nile. Even in the case of marine shells, nearly one-half of the species which now inhabit the Mediterranean also exist in our seas, while many other British species occur in Sicily in a subfossil state; thus showing that the area of distribution was once more extensive than it is at present, and that it has been since limited by climatal or other causes. From Sicily to the mouths of the Nile the distance is not considerable.

* Since writing the above, I find that at a Meeting of the Zoological Society of London, held on the 8th of July, 1856, Mr. S. P. Woodward made a very interesting and important communication on this subject. In giving a list of some land and freshwater shells from Kashmir and Tibet, which Dr. T. Thompson had collected in the Himalaya, Mr. Woodward noticed that "one half were British species, and the rest of the commonest and most widely diffused Indian forms."

Some minor facts in relation to Mr. Prestwich's discovery may be worth noticing.

One is, that the beaks of the shells in question are not eroded, as is generally the case in recent specimens. From this I should infer that the chemical nature of the water in the ancient river or estuary inhabited by the *Corbicula* was different from that of the water which composes the Euphrates or the Nile.

Another is, that the size of the semi-fossil shells exceeds that of any recent specimens which I have seen of the same form. This seems further to exemplify a fact which I have elsewhere noticed; namely,that when any species of shell is distributed over a wide area, having a northern and southern range, northern specimens are larger than those of the same species from southern localities.

The former existence of the *Corbicula* in this country does not warrant any inference that the climate must have been warmer during that period than it is at present, or that the *Corbicula* (to use a vague phrase) "retreated" south after the glacial period. It more probably was contemporaneous with the *Natica clausa* and other shells called "Arctic;" some of which have survived, while others have become extinct, in the seas which immediately surround the British, as well as the Sicilian coasts. A similar inference as to climate formerly prevailed with respect to the Mammoth. Changes in the relative distribution or juxtaposition of sea and land, an alteration in the depth of water or in the oceanic currents, an elevation or depression of the land (especially if it were alternate or sudden), the absence, diminution, or deterioration of food, the increase of natural enemies, epidemic diseases, sterility, and many other accidents (independently of climate and the agency of man), may, in the course of those unknown ages which succeeded the Tertiary epoch, have caused the extermination of many species throughout a more or less extensive area.

May 22, 1861.

Silas Bowkley, Esq., Mining Engineer, Batman's Hill, near Bilston, Staffordshire; John Edward Forbes, Esq., 3 Faulkner Street, Manchester; and Captain Francis William Henry Petrie, H.M. 11th Regiment, Portsmouth, were elected Fellows.

Gustav Bischoff, Professor in the University at Bonn, was elected a Foreign Member.

The following communications were read:

1. *On the* Geology *of a Part of* Western Australia. By F. T. Gregory, Esq.

[Communicated by Sir R. I. Murchison, V.P.G.S., &c. &c. &c.]

Introduction.—In presenting to the Geological Society the accompanying collection of specimens and this sketch of the geology of a part of Western Australia, I feel that some apology is due for laying before them a work so imperfect in its composition and arrangement, and I beg to state that I have only been induced to make the attempt in consequence of the almost total absence of any published information regarding the geological structure of this portion of the Australian continent *.

During a residence of thirty years in Western Australia, my acquaintance with its geology has been almost entirely restricted to the practical observation of its various stratified formations as presented to my view in the course of official and professional avocations, which led me over the whole of the known portion of this province; but, although thus enabled to accumulate a vast amount of notes and details, I have not had the opportunity of classifying them with any degree of certainty by the comparative study of its geology with other countries where the nomenclature and limits of the formations are well-known and established. The difficulty attendant upon the collection and preservation of fossils while travelling rapidly through a wild country has also been another obstacle in the way of my endeavours to assign exact limits to the several formations. It is therefore only since my arrival in England that, through the assistance obligingly rendered me by Sir R. Murchison, Dr. F. Hochstetter, and others, I have been enabled to deduce from my palæontological observations any certain results, which, however, although establishing a few main facts, it must be admitted leave much yet to be done to render them complete, and which it is to be hoped will shortly be followed up by more scientific observers; while the present sketch is only to be viewed as a general outline to be wrought upon by others following in the same path.

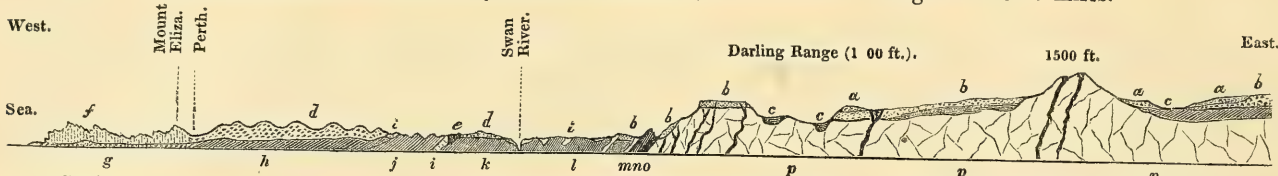
Having so far offered an explanation of the circumstances under which I venture to present to the Society the result of my labours, it will now be my endeavour, as briefly as possible, to state a few facts illustrative and explanatory of the topographical and geological features of that portion of Australia illustrated by the map and sections.

Darling Range and the Country to the Eastward.—The principal portion of Western Australia consists of an undulating table-land of syenitic granite, and may justly be considered more continental† than eruptive. It has a western escarpment, which follows the meridian line of the 116th degree of east longitude, commencing on the south coast near Cape Beaufort, and already traced northward to latitude 25° south on the Gascoyne River. The western edge of this

* A map and sections of a portion of Western Australia were presented to the Geological Society by Messrs. J. W. and F. T. Gregory, Nov. 17, 1847 (Quart. Journ. Geol. Soc. vol. iv. p. 142). The author also prepared a sketch-map of a part of the geology of Western Australia (accompanied by sections), and placed it in the hands of Mr. J. Arrowsmith, who, having engraved and published it at his own cost, has kindly presented a copy to the Society, and liberally permitted any use to be made of it. The sections at p. 477 are reduced from those engraved with this map.

† Though granite may not be anywhere eruptive, yet all granite was irruptive; but in Australia the old covering into which it was irrupted is almost completely removed by denudation over very large areas. The term "continental" is probably intended to express this fact by the author, whose absence in Australia prevents his revision of this paper whilst in the press.—Edit.

Fig. 1.—*Diagram-section across a part of Western Australia, in* lat. 32° S. Length about 40 miles.



a. Sand.
b. Ferruginous sandstone (Devonian ?).
c. Felspathic clay.
d. White and pale yellow siliceous and calcareous sand, occasionally containing coral-limestone and beds of ferruginous conglomerate, from 100 to 150 feet in thickness.
e. Bog-iron-ore.
f. Limestone with corals and shells; from 200 to 300 feet thick.
g. Compact red sandstone.
h. Variegated clay alternating with ferruginous sandstones. Cones and leaves of *Banksia* occur rarely in the upper portion.
i. Limestone.
j. Yellow clay.
k. Yellow, blue, and white clays, containing beds of limestone and bog-iron-ore, through which rise many chalybeate springs.
l. Blue and variegated yellow clay.
m. Clay-slate.
n. Quartz.
o. Mica-schist.
p. Syenitic granite, with numerous dykes of serpentine, porphyry, and quartz.

Fig. 2.—*Diagram-section across a part of Western Australia, in* lat. 25° 15′ S. Length about 200 miles.

a. Sand.
b & *c.* Red drift-sand, 50 feet thick.
d. Sandstone.
e. Cretaceous (?). In this group, which comprises both a white chalk-like (but non-calcareous) rock and ferruginous sandstones, occur *Ammonites*, *Trigoniæ*, and *Pecten*.
f. Permian (?).
g. Carboniferous (?).
h. Devonian (?).
i. Metamorphic rock.
k. Granite, gneiss, and slate, with superficial deposits of granitic breccia, ferruginous clays, thin beds of saliferous sandstones, gypsum, calcareous tufa, and beds of nodular magnesian limestone. (Similar deposits occur on the granite of fig. 1.)

elevation, for the first 300 miles on the south, rises abruptly from a sea-flat or plain of small elevation, to the height of from 800 to 1200 feet above the sea, gradually ascending for 200 miles to the eastward, to 1400 or 1600 feet, and in a few instances to 1800 and 2000 feet. Further towards the east it begins to dip under beds of saliferous sandstone, ridges of fine red sand, salt-marshes containing beds of gypsum, calcareous tufa, and felspathic clays, which are occasionally interrupted by small detached ranges of eruptive rock capped with jasper, and beautifully striped red and black metamorphic sandstones. These ranges have a sharp rugged outline, rising abruptly from the plains to an elevation of from 200 to 500 feet, and seldom extending for more than two or three miles in length, without any certain direction, although, perhaps, more frequently running N.N.W. and S.S.E.

The Western Coast.—Between the west escarpment of the table-land or Darling Range and the sea, lies a low belt of country from 20 to 60 miles in width, the upper portion of which is evidently of very recent formation, and at no very distant period has been submerged under the ocean. From Flinder's Bay northward to the Moore River, this tract of country does not generally attain to a greater elevation than from 40 to 200 feet, only reaching the latter elevation when the action of the wind has driven the sands from the sea into ridges running parallel to the coast. Those portions containing a large amount of shelly and calcareous matter have since formed, by the operation of water, into aggregations of more or less compact limestone, which give a rugged outline to the hills near the sea.

Proceeding northward from the Moore River, a nearly parallel and lower branch of gneiss from the Darling Range diverges gradually to the westward, appearing only in a few places on the Smith and Irwin Rivers, forming a valley widening to the north, which contains the coal-field of the Irwin; neither the valley nor the gneiss forms a continuous line, being covered by an elevated tract of Cretaceous (?) and Tertiary sandstone. The gneiss appears once more to the northward in a detached mass, extending from Champion Bay to the Murchison River, forming the fertile and rich mineral district in which so many valuable lodes of lead and copper have been discovered. These lodes take an almost invariable direction of N. 32° E., with a general dip of about 80° to the W.N.W., and are accompanied by parallel dykes of whinstone, quartz, or porphyry, varying from a few feet to 50 or 60 yards in breadth.

The gneiss here abounds in garnets, of rich colour, but much flawed; specimens of plumbago, tin-ore, antimony, and arsenic are occasionally found. Specks of gold have also been obtained by washing the sands in the Bowes River.

Returning southward to Flinder's Bay, the Sussex coast shows an outlying range of gneiss rising towards the east from beneath the superior deposits and extending from Cape Leeuwin to Cape Naturaliste, thus forming a bold promontory which is joined to the mainland by a low, ferruginous, sandstone formation of recent date. At

Cape Leeuwin the gneiss is composed almost entirely of felspar, forming a cliff upwards of 70 feet high, capped with water-worn blocks, the remains of an ancient sea-beach. About fifteen miles south of the cape it dips considerably, and the red sandstone shows itself where the brooks have cut through the superincumbent coast-limestone. Thirty miles from Cape Leeuwin it contains large quantities of garnets; and their fragments, with titaniferous iron-sand, are strewn on the beach for some miles.

At the Leeuwin, vertical veins of hornblende traverse the gneiss, some of them 100 feet in width. The only other locality in which the gneiss is developed to any extent is on the Pallinup River, eastward of King George's Sound, and at Doubtful Island Bay, still further east. No mineral lodes, however, have as yet been discovered in these districts; but small masses of plumbago and garnets are not unfrequent.

Igneous Rocks.—The distribution of eruptive rocks is, as shown on the map, very general. Of basalt the chief mass lies at Bunbury, rising about 30 feet above the sea; it is rudely columnar, and contains traces of copper in its natural joints, fractures, and cavities, but not in its substance, leading to the belief that it cuts a copper-lode below; there is no rock seen in contact with it. A brown clay adjoining contains water-worn quartz-pebbles, amongst which I found an opalescent stone, the size of a large pea, marked within with five spots in the form of a perfect cross [chiastolite ?]. About five miles south the basalt again makes its appearance, and at twenty miles it crosses the bed of the Capel River, and finally crops out in a continuation of the same line on the south coast to the eastward of Flinder's Bay. At Mundejung, 11 miles south of Kelmscott (which is a few miles S.S.E. of Perth), there is a small patch of basalt protruding between the syenite and clay-slate. Detached fragments are also found at King George's Sound, and on the shores of Doubtful Island Bay.

Quartz-veins.—Quartz-veins are by no means unfrequent at the higher levels, and take a general N.N.E. direction. The quartz is mostly crystalline and lustrous; and, with the exception of the veins accompanying the lodes of lead and copper, and at a few places on the Upper Gascoyne, it is seldom cellular or of the peculiar opake milk-white colour which characterizes the quartz of the gold-fields of Victoria and New South Wales. The largest mass yet found is on the face of the Darling Range, 5 miles north of Kelmscott, and forms a conspicuous mark as seen from the coast.

Slates.—The development of chlorite-schist and clay-slate is very limited, and chiefly confined to the western escarpment of the granite.

Silurian Rocks?—Of the existence of the Silurian system in this province, I have hitherto been unable to procure any positive proofs, owing to the deficiency of fossils in the localities in which, judging by analogy, there is reason to suppose it might occur. The Mount Barren Ranges are the only position in which rocks are found bearing any Silurian character, or holding that relative position with regard to other formations.

Devonian Rocks?—Following up the formations in what I have assumed to be their regular order in the ascending series, as tabulated on the map, we come to the compact felspathic clays, sandstone, and ferruginous conglomerates that cap the greater portion of the table-land of the Darling Range,—varying probably from 100 feet and under in thickness (fig. 1). All my researches have hitherto failed in detecting any fossils in this formation; but, from its resting immediately upon, and blending with the upper surface of the granite, and apparently resulting from the decomposition of the granite itself, I am led to believe that it is much older than the stratified sandstones further north, or those to the south and east of the Stirling Range, and, except in a few places in its upper portions, lower in the system than the Carboniferous formations on the Fitz-gerald and Irwin Rivers.

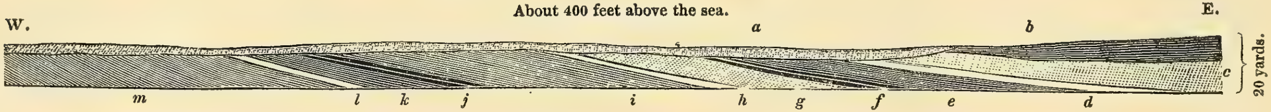
Carboniferous Rocks.—On the Carboniferous formation I would only venture to offer the additional remark, in amplification of the map and sections, that the coal on the Irwin River appears to be almost immediately covered by the Cretaceous (?) sandstone, the Saliferous or New Red being either very thin or altogether wanting (fig. 3). The coal-seams are well defined, and dip at a considerable angle; the specimens obtained from the exposed edges contain a large per-centage of carbon, but are deficient in bitumen. On the Fitzgerald River a true seam has not yet been found: the known bed is horizontal, resting unconformably upon the edges of highly elevated Carboniferous shales, and contains many distinct fragments of only semifossilized wood and pieces of infusible resin; it is in immediate contact with a band of green sand of several hundred feet in thickness, similar in appearance to the Upper Greensand in the Isle of Wight; but whether under- or over-lying, I could not ascertain with certainty (fig. 4).

Cretaceous (?) *Rocks.*—The Cretaceous (?) are the most extensively developed of the sedimentary rocks in Western Australia, and are almost exclusively siliceous in character, containing only few beds of chalk, of very inferior quality. They abound, however, more in fossils than the Carboniferous do, and, with the exception of the recent coast-limestone, more so than any other formation. Flints are rarely found in them. The bed of the Greenough River is the best spot for procuring specimens, although a few are found in the chalk-hills near Gingin (spines of Echinoderms, &c.).

Æolian Rocks of the Coast.—Turning to the coral-range that borders a large portion of the sea-coast, especially on the western shores, we have a remarkable instance of the constructive and accumulative power of the wind. The peculiar formation of these hills renders it quite evident that they are more recent than the low plain upon which they stand, as, when cut through by the rivers, they present a bold wavy stratification, always more abrupt inland, the prevailing winds being from the S.W. The bivalve shells imbedded in them almost invariably lie with their concave faces downwards*.

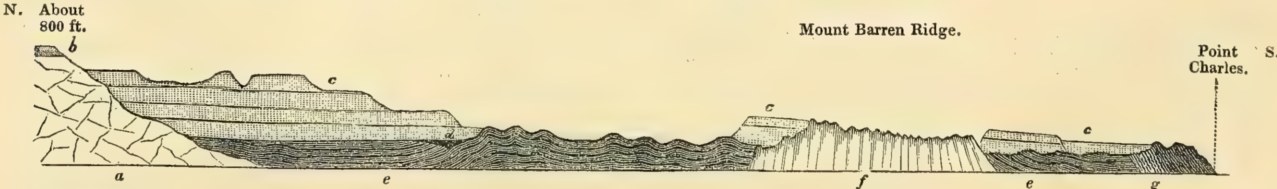
* In these calcareous beds the following species are (on the author's map) stated to occur:—*Dolium galea*, *Ranella granifera*, *Solarium perspectivum*, *Seraphs terebellum*, *Conus marmoreus*, *Phasianella australis*, *Haliotis tuberculata*, and *Bulla ampulla*.

Fig. 3.—*Section of the Coal-seams on the Irwin River, Western Australia* (lat. 29° S., ong. 115° 25′ E.). Length about 220 yards.



a. Coarse red sandstone (10 feet thick).
b. Brown sandstone and shales.
c. Red grit alternating with shales.
d. White shale.
e. Black shale.
f. Coal (2 feet).
g. Red sandstone.
h. White shale.
i. Black and white shales and sandstone.
j. Two coal-seams (5 feet).
k. Black shale.
l. White shale.
m. Brown shales with black streaks.

Fig. 4.—*Diagram-section of the Strata on the Fitzgerald River in the Southern portion of Western Australia* (lat. 34° S., long. 119° 20′ E.). Length about 20 miles.



a. Granite.
b. Sandstone.
c. Sandstone with fossil wood and gypsum (Cretaceous ?).
d. Coal.
e. Contorted shales and sandstones (Carboniferous).
f. Metamorphic sandstones and jasper traversed with dykes of trap and quartz.
g. Gneiss and granite.

Recent Elevation of the Land.—Of recent changes of elevation there are but slight evidences. The numerous beds of oyster- and cockle-shells, just above the present sea-level, of species still existent in the adjacent seas, tend to prove that there has been a gradual though slight upheaval of the coast since its first emergence from the ocean. To this may be added the fact, that the remains of a vessel of considerable tonnage have been discovered in a shallow estuary near the Vasse Inlet, and now quite shut out from the sea, which, from its appearance, I should judge to have been wrecked more than two hundred years ago, during which period the land appears to have risen about two or three feet. This, together with the fact that within the known limits of Western Australia there is not a single volcano, either active or extinct, nor any but slight evidences of volcanic agencies having been at work, goes far to prove that this portion of the Australian continent has undergone fewer changes than almost any other part of the world.

Conclusion.—A careful digest of the preceding facts, together with other observations, leads to the following conclusions, which differ but slightly from some geological notes published in the colony some ten years ago by my late brother, Mr. J. W. Gregory:—

First, that the Darling Range possesses no true anticlinal axis, but is a sudden break and descent of the table-land of the interior to the plain or sea-flat of Quartaina, which will account, perhaps, for the non-appearance of the Silurian rocks, and for the very narrow belt of chlorite- and clay-slates. Secondly, that the Darling Range attained nearly its present elevation (that is, relatively to the other strata, but not with regard to the sea-level) before the period of the Coal-formation. Before the Carboniferous (or at least Upper Palæozoic) period, the pre-existing rocks into which granite had been largely irrupted were so extensively acted upon by denudation as to be almost completely removed, their present surface-outline being nearly the same as that which they had during the Upper Palæozoic period. On that surface the Carboniferous rocks were deposited unconformably. They were again denuded, and Cretaceous(?) and Tertiary rocks were deposited unconformably on both. Since then, the country has been both elevated and depressed, more than once perhaps, but bodily and equably, and without tilting.

Note by the Editor *of the* Q. J. G. S.

Besides numerous specimens of rocks and minerals, the following fossils are comprised in Mr. Gregory's collection brought from Western Australia:—

Carboniferous fossils from Irwin River (with coal):—

Spirifer (two species).	Nautilus.
Productus (two species).	Cyathophyllum (small).
Pleurotomaria.	Encrinital stems.

Spirifer from Lyons River, East of Kennedy Range.

Coal (brown-coal) from Fitzgerald River, and a fragment of a *Cyathophyllum* from "above the coal."

Fossils of Secondary age (*Trigoniæ* and *Ammonites*) from the Moresby Range; and an Ammonite in a soft, white rock (not calcareous) from the foot of Mount Albert.

Pecten from Victoria Range, 4 miles East of Wizard Park, Moresby Range.

Fossil wood from the Moresby Range, the Stirling Range, and the Upper Murchison River.

A small Ventriculite in flint from Gingin.

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2. *On the* ZONES *of the* LOWER LIAS *and the* Avicula contorta *Zone.* By CHARLES MOORE, Esq., F.G.S.

[PLATES XV. & XVI.]

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White Lias at Beer-Crowcombe.
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Section at Stoke St. Mary.
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Section at Saltford.
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Introduction.—In a paper on the above subject by Dr. T. Wright, F.G.S., which appeared in the 'Journal of the Geological Society' for November last*, reference is made to the occurrence of the *Avicula contorta* zone at Beer-Crowcombe, near Ilminster, and a list of the organic remains from thence, amounting to thirteen species, furnished by the Rev. P. B. Brodie†, is given. In the year 1847 that gentleman accompanied me to the locality, when the fossils thus noticed were obtained. Since that time I have much increased their number, and I have also been enabled to establish the exact relative position of the *Avicula contorta* bed, which at the time of our visit was not clearly known.

It was my intention to have noticed in detail the sections that I give below in connexion with a paper which I am preparing on the Frome district, and in which I should have shown that many of the organic remains that are deposited in the fissures of the Carboniferous Limestone, and associated with the *Microlestes* and other extinct Mammalia, are derived from the Bone-bed and other beds of the *Avicula contorta* group; but, as some time will elapse before that paper is completed, and as the attention of both English and Continental geologists will have been directed to the above subject by Dr. Wright's paper, I have considered it important that any additional information in connexion with the interesting fauna and the

* Vol. xvi, p. 374, &c.

† *Loc. cit.* p. 384.

exact positions of these beds should be at once communicated; and this is the more desirable, since, unfortunately for what otherwise would have been an excellent and useful paper, that gentleman has, in my opinion, either mistaken or reversed the proper order of the lowest Liassic zones—an error attending it throughout, and which, unless corrected, may lead to some confusion.

§ 1. *The Lower Lias, &c. of Ilminster and the neighbouring district.*—Before noticing in detail the section at Beer-Crowcombe, a short description of the geological features of the district may be useful. These are to be observed in a walk from Ilminster through Beer-Crowcombe to Curry-Rival, and thence passing to North Curry; and thus within a distance of about ten miles the formations from the Upper Lias to the Keuper sandstones may be studied.

At Ilminster the Upper Lias forms the summit of the hills, capping the Marlstone or Middle Lias. The former beds are rarely more than from 6 to 8 feet in thickness, whilst the stone of the latter, for which the quarries are worked, has an average thickness of about 8 feet. Descending the hill west of Ilminster, towards the Bridgewater and Chard canal, which leads to Beer-Crowcombe and Curry-Rival, the escarpment of the Middle Lias is passed, the lower members of this zone being rarely exposed. They consist of brown and grey micaceous brick-clays, having a thickness of about 130 feet. On reaching the level of the canal, these have graduated into the upper blue marls of the Lower Lias; but sections of these are also rarely seen. In this neighbourhood they are usually covered by thick beds of gravel, derived from the Chalk and Greensand of the Blackdown range, a few miles to the south.

The canal for about four miles is continued on these Lower Lias marls, which at Ashill, a little to the west, have been proved to a depth of 80 feet. At Beer-Crowcombe the canal enters a tunnel, excavated on the south side in the Lower Lias. It emerges again at Wrantage, about two miles to the north, under a bold escarpment of the variegated marls of the New Red Sandstone. As these formations have here been uplifted, with a slight dip to the south, a good section of them was made in cutting the canal. It was from the southern end that the few blocks of the *Avicula contorta* bed mentioned in the Rev. P. B. Brodie's communication to Dr. Wright were obtained. Its position will be recognized as the "Flinty Bed," No. 81, of the accompanying section (p. 486).

Passing down the northern escarpment of the beds before-mentioned, and crossing the valley towards North Curry, the Keuper sandstones, with their characteristic plant-beds, may be seen in the roadside leading to Morden, dipping under the formations already noticed; whilst a little north of the village another escarpment of these Keuper beds stretches away, as far as the eye can reach, towards Langport, bounding the alluvial plain which extends to the Bristol Channel.

In one of the first blocks of Keuper I examined at North Curry I was reminded of the Reptiliferous sandstones near Elgin *, by finding

* See Quart. Journ. Geol. Soc. vol. xvi. p. 446.

in it an imperfect rib-bone. It also yielded traces of fish-scales and plants. A character these sandstones possess in common with some of the Scottish beds, particularly those of the Quarry Wood range near Elgin, is that they contain a number of flattened pellets of marl, which, on being weathered out of the stone by exposure, leave on the surfaces of the blocks their rounded or oval casts.

At Knap, west of North Curry, there is a large sandstone quarry in which the beds are lower than those just mentioned; but the passage-beds between them are unknown. Sections are given below, p. 486. At this place the beds are non-fossiliferous.

Sections at Beer-Crowcombe.—My friend Mr. Brodie, in his communication to Dr. Wright on the beds exhibited at the Beer-Crowcombe quarries, remarks that "there are several thin beds of limestone, but not so thick as those in Warwickshire*". From the following section, which I made in the year 1850, it will be seen that they are of much greater thickness and importance than his remark implies, or than our hurried visit to them in 1847 enabled him to realize; indeed I know of no other section in this zone of rocks fuller or more instructive.

Sections of the Beds in descending order.

At Ilminster.

	ft.	in.
Upper Lias	8	0
Middle Lias. Marlstone	8	0
Various brown and grey micaceous brick-clays, with intercalated sandstone and occasional impressions of organic remains	130	0
Lower Lias. Upper blue marls on the line of canal and at Ashill	80	0

At Beer-Crowcombe—Mr. Hornibrook's Quarry.

		ft.	in.
	Vegetable soil	2	9
	1. Bastard rock	0	4
	2. Shale	1	8
	3. Bastard rock	0	9
	4. Shale	1	9
	5. Bastard rock	0	5
	6. Shale	2	0
	7. Bastard rock	1	0
	8. Shale	2	0
	9. First buff coat	0	5
	10. Shale	0	7
	11. Bastard rock	0	2
	12. Shale	0	4
	13. Second buff coat	0	4
	14. Shale	0	2
	15. Third buff coat	0	2
	16. Shale	0	2
	17. Bastard rock	0	2
	18. Shale	0	3½
	19. Glassy blue bed	0	4½
	20. Shale	1	5
	21. Jack blue bed	0	10
	22. Shale	0	2
	23. Mumbling bed	0	5
	24. Shale	0	2
	25. Mumbling bed	0	6
	26. Shale	0	2
	27. First Come-by-chance	0	3
	28. Shale	0	5
	29. Second Come-by-chance	0	4
	30. Shale	0	1
Ammonites planorbis zone.	31. First black rock	0	5
	32. Shale	0	1
	33. Second black rock	0	6
	34. Third black rock	0	6
	35. Shale	0	6
	36. Fourth black rock (bottom-bed)	0	8

* Loc. cit.

Continued in Mr. Vile's Quarry.

		ft.	in.
Saurian zone.	37. Hookstone clay. (Numerous scattered Saurian remains.)...	2	0
	38. Hookstone	0	8
	39. Shale....................	0	6
	40. Clay-bats	0	4½
	41. Shale....................	0	10
	42. Thick burrs	0	9
	43. Shale....................	1	0
	44. Milley burrs	0	5½
	45. Shale....................	0	3
	46. Fire-stone..............	0	3
	47. Shale....................	1	4
	48. Paving-bed	0	4

		ft.	in.
Saurian zone.	49. Shale....................	0	1
	50. Paving-bed..............	0	4
	51. Shale....................	1	4
	52. Red bed..................	0	4
	53. Shale....................	0	1
	54. Black bed..............	0	4
	55. Shale....................	0	6
	56. Clog-stone..............	1	3
	57. Shale....................	2	2
	58. Red fire-stone..........	0	5
	59. Shale....................	1	0
	60. Blue bed	1	0
	61. Shale....................	2	0
	62. Dunster	1	0

Continued in Mr. Banfield's Quarry.

		ft.	in.
White Lias zone.	63. Shale	1	10
	64. White Lias..............	0	8
	65. Shale	0	6
	66. White Lias..............	0	6
	67. Shale	0	3
	68. White Lias..............	0	3
	69. Shale	0	3
	70. White Lias..............	0	2
	71. White Lias..............	0	6

		ft.	in.
White Lias zone.	72. Shale	0	2
	73. White Lias..............	0	3
	74. Shale	0	3
	75. White Lias..............	0	6
	76. Shale	0	4
	77. White Lias..............	1	0
	78. Rubbly Bed	0	5
	79. White Lias (bottom-bed)	1	1

The position of the "Flinty bed" in the *Avicula contorta* zone below was satisfactorily established by the united testimony of several labourers who assisted in the excavation of the tunnel, by an examination of the waste-heaps, and by several sections in the neighbouring escarpments.

		ft.	in.
Avicula contorta zone.	80. Grey shaly marl ...	5	6
	81. "Flinty bed" (very fossiliferous)	1	0
	82. Blue shaly marl......	3	0
	83. Pale blue stone, with vegetable-like markings	1	2

		ft.	in.
Keuper.	84. Light blue marl...... passing into	6	0
	85. Variegated blue and red Keuper marls, with alabaster, about	100	0

Sections at North Curry and Knap.—Following below the variegated marls (the precise thickness of which is unascertained), come in the Upper Keuper Sandstones of North Curry: thus—

Section in the Lane near the Church.

	ft.	in.
Various beds of dull grey and brown sandstone, enclosing nodules of marl, and containing *Estheria*, Plants, traces of Fish-scales, and a Reptilian bone	3	6
(The above thicken in their dip to the south.)		
Blue nodular marl	1	0
Red marl	2	0
Light blue marl	0	3
Compact red marl in thin laminæ	5	0
Nodular marl	2	0
Blue marl	1	0
Variegated red and blue marl ...	4	0
Red shale, with quartz-grains ...	6	0
Red and blue compact marls, about	40	0

Section of still lower beds at Knap; $1\frac{1}{2}$ mile distant.

	ft.	in.		ft.	in.
Variegated marls	5	0	Sandstone	1	10
Deep-red marl	1	2	Red marl	1	10
Chocolate-coloured marl	2	4	Grey sandstone	2	2
Compact grey stone	0	2	Do. do.	2	2
Grey marl	0	2	Do. do.	2	3
Red marl	1	2	Do. do.	0	10
Grey marl	0	9	Do. do.	3	6
Grey sandstone, thin courses	3	0			

The beds at Knap are covered by a drift composed of cherty pebbles. They afford no indications of organic remains; but lithologically they present a close resemblance to the Upper Keuper Sandstones of Worcestershire.

§ 2. *Subdivisions of the Lower Lias, &c.; the true position of the "White Lias."*—In the division of the Liassic beds, Dr. Wright has followed Dr. Oppel of Munich in adopting a series of Ammonite-zones,—a plan which, though generally convenient, may not always be safe, since it is probable that at any time the range of specific forms may require to be extended.

The zones thus adopted (by Dr. Wright) in descending order are,—

1. *Ammonites raricostatus* zone.
2. *A. oxynothus* zone.
3. *A. obtusus* zone.
4. *A. Turneri* zone.
5. *A. Bucklandi* zone.
6. { *A. planorbis* zone, including White Lias. Ostrea-beds. }
7. *Avicula contorta* beds, Keuper.

Between the zones 5 and 6 Dr. Oppel has placed a zone of the *Am. angulatus*; but this is a species that has a considerable range into the other zones, and is therefore properly omitted. I do not take exception to any of the divisions *above* the *Am. planorbis* beds, but I propose inserting *below* those beds two other zones, viz.:—a Saurian zone, and the White Lias zone of Mr. Smith. When I refer, therefore, in the following remark to the "White Lias," it is to be understood as everywhere occupying a position immediately *above* the *Avicula contorta* zone and at the base of the true Liassic series. Its position seems to have been mistaken by Dr. Wright, who has, in my opinion, been misled, by the quarrymen in the different localities, into supposing that their local beds of "White Lias," or what would be a white-looking band of stone in a blue-lias quarry, is the true White Lias of Smith, which is a series of beds occupying a uniformly lower position.

I propose, therefore, the following arrangement:—

6. *Ammonites planorbis* zone.
7. Enaliosaurian zone.
8. White Lias. } Rhætic Formation.
9. *Avicula contorta* beds. }
10. Keuper marls.

In my section at Beer-Crowcombe, the beds Nos. 1 to 30, which are superior to the *Am. planorbis*, represent one or more of the higher zones; but, as at this place I have found no *Ammonites* in them, their divisions are undeterminable.

In the remaining portion of my paper, the remarks I shall offer will have more especial reference to the beds which Dr. Wright has included in the *Am. planorbis* zone and to those following below. I shall then show the desirability of adopting a different classification for those he has included in the group characterized by the *Avicula contorta*, which latter beds are placed by Dr. Wright with the Keuper; and finally offer reasons for removing them, with the "*White Lias*," to the "*Rhætic Formation*" of Continental geologists.

Dr. Wright's views of the position of the White Lias.—When describing the zone of the *Ammonites planorbis*, Dr. Wright remarks (*loc. cit.* p. 389) that "in general it consists of a series of thin, greyish or bluish, argillaceous limestones, with alternating beds of laminated shale; or sometimes the entire series forms a thick-bedded, argillaceous, cream-coloured limestone, called the *White Lias*, by William Smith. In the upper half of this group of beds, *Ammonites planorbis*, Sow., is found in great numbers, compressed in the shales, with its white shell more or less preserved; in the lower portion of the series, *Ostrea liassica*, Strickland, appears in great numbers; and beneath these strata are three or four beds of hard limestones (or 'firestones'), in which the finest skeletons of *Enaliosauria* have been discovered."

Again, at p. 396 it is stated that the "White Lias series of the section at Saltford (p. 400) represents the *Am. planorbis* beds: here also the relation of that zone to the Saurian beds below, and to the *Am. Bucklandi* beds above, is well shown."

In the table given at p. 411 the following arrangement and description of the beds are adopted:—

(Part of) Ammonitiferous* beds.	Zone of *A. planorbis.*	*f.* Greyish or light-coloured limestones, in thin beds, interstratified with finely laminated shales; the limestones forming the paving-beds of Warwickshire, and the White Lias of Dorsetshire, and containing *Am. planorbis*, *Am. Johnstoni*, *Lima punctata*, &c.
	Ostrea-beds.	*g.* Hard dark-grey limestone, containing *Ostrea liassica* in great abundance, with skeletons of *Plesiosaurus megacephalus*, *P. Hawkinsii*, *Ichthyosaurus intermedius*, and *I. tenuirostris.*
Non-Ammonitiferous beds.	Zone of *Avicula contorta.*	*h.* Dark shales, with thin bands of limestones, often pyritic, and thin beds of light-coloured micaceous sandstone, with a thin band of bone-breccia near the base. These contain *Avicula contorta*, *Pecten Valoniensis*, and *Pullastra arenicola.*

From the above extracts it will appear evident that Dr. Wright has incorporated the White Lias of William Smith, Conybeare and Phillips, and other geologists, with the *Ammonites planorbis* zone,

* Dr. Wright in this table has divided the Lower Lias into *Ammonitiferous* and *Non-ammonitiferous* beds,—the former ending with his *Am. planorbis* zone, the latter including the Ostrea-zone (or true White Lias) and the *Avicula contorta* zone. This division is not desirable; for, although *Ammonites* are rare in the lower beds of the Lias, they are not altogether absent. I have obtained small flattened specimens from the Saurian beds; and Mr. Tomes informs me they are also to be found through the whole of the Warwickshire Liassic series.

and has placed the Saurian beds either in or below the Ostrea-beds, the latter being in fact the equivalents of the White Lias of those authors.

White Lias at Beer-Crowcombe.—On referring to the very full section I have given of the Liassic beds at Beer-Crowcombe (p. 485) the *Am. planorbis* zone will be seen to commence with the bed No. 31, and appears to have a vertical range downwards to the "Hookstone clay," 37, lower than which I have not observed it. This Ammonite is abundant; and is sometimes found with the *Trigonellites* in place.

Including the Hookstone clay just mentioned, in which there are numerous scattered Saurian remains, all the beds following, to the White Lias, may be said to constitute a *Saurian zone,* as these remains may be found more or less abundantly throughout them; though, as stated by Dr. Wright in his remarks on the Street section, to which I shall presently refer, the finest examples are usually from the lowest beds.

Immediately below the Saurian zone will be found the true position of the White Lias, whilst its continuation downwards into the *Avicula contorta* beds is shown in my section; and beneath these, again, are the variegated marls of the Keuper, and their underlying sandstones.

Section at Street.—The most important sections from Somersetshire given by Dr. Wright are those of Saltford, near Bath, and Street. The latter is distant about 14 miles in a direct line from the one at Beer-Crowcombe. The names of the beds in the latter locality are those by which they are known to the quarrymen. On comparing the Beer-Crowcombe section with that at Street, although the beds vary in thickness, which might be expected at such a distance, a parallel may be observed between them, and some of them are really called by the same names. Thus, in the Saurian zone of the Street section, the Firestone bed, No. 29, and the Grey Clog, No. 25, of Dr. Wright, occupy the same relative position, and are the probable equivalents of the "Red Firestone," No. 58, and the "Clogstone," No. 56, of my section at Beer-Crowcombe. The "Yellow laminated clay," No. 3, at Street answers the description and occupies the position of the "Hookstone Clay," No. 37, at the latter place; whilst, reckoning from the base of the Saurian zone to the highest bed in the *Am. planorbis* series, there is a difference of only one in the number of beds in the two sections. The quarries at these localities are therefore undoubtedly on the same horizon. They are chiefly worked at both places for the paving-beds, the best of which are found in the lowest part of the Saurian zone. I have no doubt that, had the section given by Dr. Wright at Street been continued downwards, the White Lias, as shown in my section at Beer-Crowcombe, would have been found.

Section at Stoke St. Mary.—In order still more clearly to point out the invariable position of the White Lias, I give particulars of a section occurring at Stoke St. Mary, near Taunton, which I have lately had an opportunity of visiting in company with the Rev. W. A. Jones, F.G.S. This section is some miles south-west of that at Beer-Crowcombe. Although slight discrepancies will appear, nearly all the lower beds are called by the same names, occur in the same order, and are usually of the same thicknesses as those at Beer, and Saurian remains are found in the same zone as at that place and at Street.

This section is the more interesting as the workings are carried down through the Saurian zone to the lower beds of the White Lias.

For the sake of comparison I have appended to the Stoke St. Mary beds the numbers they represent in the Saurian zone at Beer-Crowcombe. The White Lias beds vary much in different localities.

Section at Stoke St. Mary.

Zone	Bed	ft.	in.
	Gravel	5	0
Am. planorbis Zone.	34. Grey Lias	0	10
	35. Shale	1	0
	36. Pap-meat	0	8
	37. Shale	1	2
Saurian Zone.	38. Rough Blue bed	0	10
	39. Blue shale	1	6
	40. Clay-bats	0	6
	Shale	0	6
	[Several beds not recognized here.]		
	44. Sandstone	0	4
	45. Shale	0	2
	46. Sandstone	0	3
	47. Shale	1	6
	48. Paving-bed	0	4
	49. Shale	0	3
	50. Paving-bed	0	4
	51. Shale	1	3
	52. Sandstone	0	4
	53. Shale	0	2
	54. Cockle-bed	0	8
	55. Shale	0	2
	56. Clog-stone	0	8
	57. Firestone-clay	2	0
	58. Firestone	0	4
Saurian Zone.	59. Shale	0	9
	60. Blue Lias	1	1
	61. Shale	3	0
	62. Dunster	1	0
	63. Shale	1	8
	64. Blue Lias	0	9
	65. Shale	0	2
	66. Blue Lias	0	9
	67. Shale	0	3
White Lias Zone.	Buckles	0	2
	Top-size White Rock	0	6
	Shale	0	4
	Second-size White Rock	0	6
	Shale	0	3
	Third-size White Rock	1	0
	Shale	0	1½
	Thin stripe	0	1½
	Shale	0	1
	Thin stripe	0	1½
	Fourth-size White Rock	1	1
	Shale	0	2
	Grab Rock	0	9
	Shale	0	3
	Dunster Bags	0	3
	Dunster Bags	0	3

No direct passage leading into the above-mentioned beds from the red marls is to be observed in the escarpments, and therefore no trace of the *Avicula contorta* zone. Wells have been sunk to a depth of 60 feet in the marls, to obtain water. In the sides of the turnpike-road leading to Taunton, thin beds of Keuper are present with *Posidonomya minuta.*

Section at Pibsbury.—In addition to the sections already enumerated, there are numerous quarries in which the lower zones of the Lias are worked in the district south of Street, at King-Weston, Keinton, Sparkford, Somerton, and on the line of road between Langport and Long Sutton. Langport is on the Keuper; and on ascending the hill from thence to Huish-Episcopi, the White Lias beds are exposed in a roadside-cutting, and in an adjoining quarry. These beds dip to the east, and at a mile and half from Langport, pass under others which are worked on the same line of road at Pibsbury, a section of which, given below, shows that the latter are undoubtedly on the same horizon as the beds given by Dr. Wright in the Street section, which are distant about ten miles.

Section at Pibsbury.

Equivalent bed at Street.	No.		ft.	in.	Equivalent bed at Street.	No.		ft.	in.
7.	1.	Corn-size	0	6	18.	14.	Shale	0	2
8.	2.	Shale	0	3	19.	15.	Black bed.........	0	7
9.	3.	Thin bed	0	4	20.	16.	Shale	0	7
10.	4.	Shale	0	4	21.	17.	Pig's Paviour ...	0	3
11.	5.	Milley-burrs ...	0	6	22.	18.	Shale	0	3
12.	6.	Shale	0	6	23.	19.	Blue Clog	0	11
	7.	Bunch-back......	0	4	24.	20.	Shale	1	2
	8.	Shale	1	0	25.	21.	Dun Paviour ... (Grey Clog) ...	0	5
13.	9.	White stone ...	0	4					
	10.	White stone ...	0	4	27.	22.	Pond-size.........	0	5
14.	11.	Shale	0	10	28.	23.	Lias-paviour ...	0	4
15.	12.	Cream-bed	0	2	29.	24.	Tomb-size	0	6
16, 17.	13.	Firestone	0	7	30.	25.	Bottom-bed	0	4

In this section the beds 1 to 6 of Street, which would represent the *Ammonites planorbis* zone, are not present.

A quarryman at Pibsbury had also worked at Street, and was able to correlate the beds with those in that locality, and to point out their local variations. Thus, he informed me that the "Bunch-back" and underlying shale (Nos. 7 & 8) were wanting at Street; the "White stone," instead of being one bed, was divided into two, and that the "Firestone," No. 13, was the "Red Liver" and "Black bed" of Street (Nos. 16 & 17) "run together." Inquiries of the quarrymen working in this zone of rocks, for the White Lias, generally resulted in the remark that they did not work down to it.

Section at Long Sutton.—Passing to Long Sutton, about two miles further on, the same beds are again worked, in a quarry belonging to the Earl of Burlington. A fault at the west of this village has brought up the White Lias beds, the position and thicknesses of which are admirably shown in a section worked almost entirely in this zone at Steven's Hill, in which between the Saurian zone in the quarries just mentioned, and that of the *Avicula contorta*, not less than *thirty-five* beds of White Lias are exposed.

Section of White Lias at Steven's Hill, Long Sutton.

	ft.	in.		ft.	in.
1. Splintery beds of Blue Lias (bottom of the Saurian zone)	2	0	11. Shale	0	4
2. Shale	2	0	12. White Lias	1	0
3. White Lias	0	8	13. Shale	0	2½
4. Shale	1	0	14. White Lias	0	5
5. White Lias	0	5	15. Shale	0	2
6. Shale	0	6	16. White Lias	0	2½
7. White Lias	0	6	17. Shale	0	4½
8. Shale	1	2	18. White Lias	0	3
9. White Lias	0	9	19. Shale	0	6
10. White Lias	0	5½	20. White Lias	0	7½
			21. Shale	0	7
			22. White Lias	0	2½

Section of White Lias at Steven's Hill, Long Sutton (continued).

	ft.	in.		ft.	in.
23. Shale	0	7	31. Shale	0	0½
24. White Lias	0	2½	32. White Lias	0	2
25. Shale	0	3	33. White Lias	0	9
26. White Lias	0	6	34. Shale	0	3
27. Shale	0	7	35. White Lias	0	8
28. White Lias	0	6	36. White Lias—Bottom-bed	1	3
29. White Lias (Coral-bed)	1	0	37. Blue Marl	5	0
30. White Lias	0	6			

Since my paper has been prepared, Mr. Kershaw (a section of whose quarry at Wilmcote is given by Dr. Wright) has been through the district accompanied by Mr. Tomes of Welford Hill, both of whom are well acquainted with the Warwickshire beds. After their examination, they entirely agree with me that the true White Lias occupies a lower position, and is quite distinct from the Street beds. They were fortunate enough to make out a fact that had escaped me in the Steven's Hill section,—namely, that the bed No. 29 contained a great number of Corals, most of which, having become decomposed, have left nothing but their casts in the stone, though in a few instances the Coral is preserved.

In a note to me, Mr. Tomes describes it as a "branching species, several inches in height, with an epitheca having numerous and regular concentric wrinkles, and delicate but distant longitudinal striæ; probably of the genus *Cladophyllia*."

Section at Saltford.—In the section at Saltford (*l. c.* p. 400) constructed by Mr. W. Sanders of Clifton, the position of the White Lias series is correctly given, though I should be disposed to include in it only the beds Nos. 9 to 22. In a reference to his section (*l. c.* p. 396), the Saurian beds are supposed to follow *beneath* the White Lias; but in this section, as at Street and Beer, they are represented by the limestones and shales above.

If there be any zone more persistent than another, it is that of the White Lias. Wherever the *Avicula contorta* beds are exposed, the representatives of the former may be expected to be present immediately overlying them.

Other sections in Somersetshire.—In addition to the sections already mentioned, others in which these beds may be found occur at Fivehead, Hatch, Uphill, Somerton, and in a deep sinking for coal at Batheaston, made in 1812, through the whole Liassic series, a section of which is given at p. 262 of Conybeare and Phillips's 'Outlines of Geology of England and Wales.' Near Bristol they occur at Cotham, Bedminster, and Pylle Hill. In a paper* on the Linksfield shales, I pointed out the correlation of those beds with the latter section, and the presence of the White Lias zone occupying the same position, as far north as Elgin.

Sections at Batheaston and Paulton.—In the section given of the beds at Batheaston, p. 262, of Conybeare and Phillips's 'Outlines,' under the head of the "Upper Marls" are included all the beds of

* Quart. Journ. Geol. Soc. vol. xvi. p. 445.

the Upper Lias, the Middle Lias, or Marlstone, and also the Upper Marls of the Lower Lias, with some of their limestones, having altogether an aggregate thickness of 220 feet. Then follow what those authors (C. & P.) call the "True Lias beds," including the White Lias at its base; and their "Lower Marls," down to the New Red ground, include the *Avicula contorta* series.

Section at Batheaston.

		ft.	in.
True Lias beds.	Upper Marls	220	0
	Hard rock	18	4
	Blue stone	5	1
	Hard blue stone	12	1
	Stone	2	0
	White Lias rock	10	0

		ft.	in.
Lower Marls.	Blue Marl	6	0
	Stone	0	6
	Clay	0	9
	Rough blue marl	0	5
	Black marl	10	0
	Light-blue marl	2	0
	Red ground of New Red Sandstone (Keuper).		

A section also of the beds at Paulton near Bath is given on the same page.

		ft.	in.
	Inferior Oolite	18	0
	Upper Lias marls	120	0
True Lias beds.	Grey and blue Lias Rock*	6	0
	Sun bed	1	6
	White Lias	12	0

	ft.	in.
Blue marl	6	0
Claystone, &c.	3	0
Black marl	6	0

Section at Westbury.—Dr. Wright has given a section of the *Avicula contorta* zone at Westbury, which commences in the Ostrea-bed, described by him as being one of the lowest in the "*Am. planorbis* series," but which, I consider, belongs to the true White Lias, and is equivalent to those beds at Saltford, Beer-Crowcombe, Stoke St. Mary, &c.

In this view I am again confirmed by the above-mentioned authors, who at p. 263 of the 'Outlines,' &c., give the following section at Westbury-on-Severn.

Section at Westbury-on-Severn.

		ft.	in.
	White Lias	10	0
Avicula contorta zone.	Blue shale	10	0
	Black shale	12	0
	Green siliceous grit, containing abundant bones, well known, here and at Aust, as the bone-Bed	1	0
	Black shale	2	0
	Green grit	0	6
	Black shale	2	0
	Greenish marlstone and red marls of the Keuper	18	0

In all these sections it is thus seen that these authors place the White Lias as a distinct zone immediately overlying the *A. contorta*

* Over this portion of the Somersetshire coal-field many of the beds are much reduced in thickness. The Middle Lias, for instance, which in some parts has a thickness of upwards of 100 ft., is here represented by beds of but 4 or 5 feet in thickness; and the upper beds of the Lower Lias are also wanting.

bed, in which the beds correspond with every other section with which I am acquainted.

When speaking of the White Lias, they say that it takes a high polish, and may readily be employed for lithographic purposes, a description which corresponds with that given of the beds at Lyme by Dr. Wright.

Sections in Gloucestershire and Warwickshire.—I am unacquainted with some of the sections in Gloucestershire and Warwickshire given by Dr. Wright; but in that at Aust Cliff, I am disposed to consider the nine beds above the *Avicula contorta* zone to be the representatives of the White Lias, and not of the *Am. planorbis* zone. In Warwickshire, the best section is afforded by the quarry of Messrs. Greaves and Kershaw, at Wilmcote, near Stratford-on-Avon (*op. cit.* p. 386), in which the beds are shown to be very similar to those at Street. My correlation of the latter beds with those at Beer-Crowcombe being admitted, it will at once be evident that in this locality the upper beds, Nos. 1 to 7, represent the *Am. planorbis* zone, and Nos. 8 to 23 or 24 the Saurian zone, whilst the "Hard crystalline limestones," &c., which follow, are in all probability the representatives of the White Lias. With this arrangement the correlation of the zones with those at Street and Beer-Crowcombe is established.

On referring to a note which I some time ago received from Mr. Tomes, I find that he recognizes the position of the White Lias of that district when he says: "The Warwickshire White Lias appears to represent a different zone from the Somersetshire White Lias, being *very low* in the series." He then points out its position by a rough section, in which I recognize it as occupying the same zone as in all other localities. The position of the *Avicula contorta* beds is in every case correctly given by Dr. Wright, as following at the base of each section, lying above the Red Marls.

In the neighbourhood of Tewkesbury, Dr. Wright states there are several good exposures of the infra-ammonitic beds (meaning those below the *Am. planorbis* zone), from which were obtained numerous fine examples of *Ichthyosauri* and *Plesiosauri*, and that he possesses vertebræ of *Plesiosaurus rugosus* from a bed of *White Lias* at Woolridge Common. These beds, again, are evidently on the horizon of the Saurian beds of Somersetshire; and although the bed at Woolridge Common from whence the *Plesiosaurus* was obtained may be a white-looking lias, it is not the basement White Lias zone, in which, as I have elsewhere stated, no Saurian remains have ever been found.

Sections at Lyme Regis.—The chief point of interest advanced by Dr. Wright respecting the Lyme section is that in which he places the Saurian zone, not on the horizon of those beds in Somersetshire and Warwickshire, but in the *Am. Bucklandi* zone which overlies them. It is not impossible that circumstances may have been favourable to a larger development of Enaliosaurian life in the Liassic seas at the point where these beds are now found, especially when it is considered that their remains are occasionally, though but rarely, found in the same zone elsewhere; but, supposing those given by Dr. Wright in his section (p. 401) at Broad Ledge to be the true equivalents of his *Ammonites Bucklandi* beds at Street (p. 390), there would still have to be accounted for at Lyme the *Am. planorbis* zone, and my "Saurian beds" below, which, in such a development of the Lias as occurs at Lyme, can scarcely fail to have their representatives.

Two sections of what Dr. Wright considers the *Am. planorbis* zone are indeed given, one of which is at Up-Lyme, the other at Pinhay Bay. In their description, the stone is stated to be "cream-coloured, and so hard and close-grained that it might be used for lithographic purposes." This answers precisely to the character of the true White Lias; and I have little doubt that it is such. Its place is therefore on the zone of that series as given in my Beer-Crowcombe and Stoke sections, and in that (described by Dr. Wright) at Saltford, where it immediately overlies the *Avicula contorta* beds. It is therefore much lower than the *Am. planorbis* beds. It then appears to me that neither the latter zone nor the Somersetshire Saurian zone has been recognized at Lyme by Dr. Wright; and in this case, I should incline to the view (should the whole of the Lyme section have been given) that some of the lower beds which he has classed under the *Am. Bucklandi* zone may be their representatives, even though it necessitated giving to the *Am. Bucklandi* and other shells a greater vertical range than they have hitherto been supposed to attain.

True position of the White Lias.—I have thus shown that the White Lias occupies a position at the base of the Liassic formation,—that, of all Dr. Wright's sections, its true place is only recognized at Saltford, though here—and also when he notices the same zones at Lyme, Wilmcote, &c. he confounds them with the *Am. planorbis* beds,—and that intermediate between the White Lias and the latter are the Saurian-bearing beds. To illustrate the difficulties created by these transpositions, I need only remark that, whilst in the sections generally Dr. Wright places the Saurians in the *Am. planorbis* zone, at Wilmcote he places them in the Ostrea-beds, or true White Lias, at the base of the formation; and at Saltford he places them below the White Lias, where only the *Avicula contorta* beds are to be found.

§ 3. *The Rhætic Formation.*—In the preceding observations I have throughout referred to the White Lias zone as constituting a member of the Liassic formation, with which hitherto it has always been associated. I now propose its removal from that formation, and its classification with the *Avicula contorta* group, under the above designation. For this proposal my reasons are, 1st, that over a very extended area the "White Lias" forms a very persistent line of demarcation, and is almost invariably present, overlying the *Avicula contorta* beds wherever they are exposed; 2nd, that by its colour and lithological character, being dense and close-grained, it forms a marked contrast to the large flaggy Saurian limestones of the Lower Lias immediately above; and 3rd, the great distinction which is presented by a consideration of the faunæ of the two zones. In the "White Lias" the organic remains are rare, and of very few specific forms. *Ostrea liassica*, Strickl., *Plicatula interstriata*, Ew., and *Modiola minima* prevail, and also characterize the beds below; whilst from other districts may occasionally be added *Monotis, Lima, Cypris, Estheria,* and a few small univalves (usually in casts) of doubtful specific forms, but which appear to have their representatives rather in the *Avicula contorta* zone below, than in the "paving-beds" above; and it should be remembered that when these latter beds were being deposited, the ocean teemed with Enaliosaurian life, of whose presence in the "White Lias" I as yet know of no evidence.

The "White Lias" presents evidences of a slow deposition; and each bed appears subsequently to have been subjected to erosion. The surfaces of many of the blocks are covered with *Cypridæ*. A period of rest between the deposition of the several beds is shown by the presence of colonies of boring Mollusks, which have left innumerable tubular perforations passing downwards in the beds.

Following the above, there would then be included in the "Rhætic formation" all the beds lying superior to the variegated marls of the Keuper,—the most noteworthy being the shelly bands yielding the *Avicula contorta*, and the Bone-bed. Until lately these were included with the Lower Lias; but, the investigations of Sir P. Egerton, Agassiz, and others having demonstrated that the latter bed contained a peculiar fauna, they have become recognized as Triassic, or as upper members of the New Red Sandstone, and they are retained in Dr. Wright's Table of Strata (*op. cit.* p. 376) as the uppermost zone of the Keuper.

Meanwhile there have been discovered, on the continent, beds of great thickness *between* the Lias and the Keuper, the representatives of all of which were apparently wanting in this country.

In ascending order these are:—

1st. The St. Cassian and Hallstadt beds (which have yielded more than 800 species of Mollusca); and

2nd. The Kössen stage, or, as it is now proposed to be termed by Mr. Gümbel the State-Geologist of Bavaria, the *Rhætic formation,*—a designation recognized by Professor E. Suess, of the Imperial Museum of Vienna, and which it will be convenient to adopt for the beds under notice, which in this country are the representatives of the second stage. In this division are comprehended the 'Deposito d'Azzarolo' of Italian geologists, as well as the Starkenberg beds and Dachsteinkalk of Austrian geologists. In the Austrian Alps the formations above noticed attain a thickness of from 4000 to 5000 feet. This is the important series of rocks of which, in this country, the beds before referred to (rarely averaging more than 35 feet in thickness, and intervening between the Lias and the Keuper) are the diminutive representatives.

§ 4. *Rhætic Organic Remains.*—The organic remains in this formation in England are derived chiefly from the Bone-bed and the beds yielding the *Avicula contorta*. At Beer-Crowcombe the Bone-bed appears to be wanting; but a few fish-remains that usually accompany it will be noticed from the latter bed at Beer-Crowcrombe. I have assembled a remarkable fauna from a drift (derived from the Bone-bed) near Frome, an account of which I must reserve for another occasion. As, however, I shall have to notice below some *Mollusca* from the *Avicula contorta* zone of this neighbourhood, I give a short description of a very remarkable section in which those beds occur.

In the Vallis, near Frome, there are quarries worked for the Carboniferous Limestone, some of the beds of which have their upturned edges capped with horizontal Inferior Oolite. In a section near Hapsford Mills I noticed a conglomerate with a few thin intermediate layers of stone and clay. The limestone in this section has a dip of 35°, N.W., and is worked to a depth of 15 feet. Lying upon it there is a band of blue clay 4 inches in thickness, which, on close examination, I found to contain a very interesting fauna. Associated with remains of Fishes and Reptiles of the Bone-bed age, it yielded *Avicula contorta, Ostrea interstriata* abundantly, *Pecten Valoniensis,* with other genera never before noticed in beds of this age, such as *Chiton, Pollicipes,* &c. This clay is succeeded by a dense conglomerate of rounded siliceous pebbles, 2 feet thick, and containing, though rarely, fish-teeth and scales; another blue clay of 4 inches succeeds, but without organic remains; then a grey conglomerate, 4 inches, upon which there are courses of grey or cream-coloured nodular limestone, intermingled with a grey clay, 1 foot in thickness. In this, organic remains are extremely rare. Specimens of *Estheria,* Insects, and one block containing Plant-remains are all I have obtained. Above the latter are beds of Inferior Oolite, 12 feet in thickness, conglomeratic at their base.

The interposed beds of conglomerate, stone, and clay between the Inferior Oolite and the Carboniferous Limestone, although but 4 feet in thickness, may represent in this section the geological eras of the *White Lias,* the *Estheria-beds* of Warwickshire and Gloucestershire, the *Avicula contorta zone,* and the *Bone-bed*; so that, were the "White Lias" to be considered to represent a distinct formation, not less than four geological eras would be exhibited in one section of about 30 feet in depth.

A thin band of conglomerate, $1\frac{1}{2}$ inch thick, of precisely the same aspect, and the same age, is present in the Uphill railway-cutting.

Dr. Wright remarks (*op. cit.* p. 409) that he has "shown that the *Conchifera* are special" to the *Avicula contorta* zone. In the blue clay lying between the conglomerate and the Carboniferous Limestone the *Ostrea interstriata* is the most abundant shell. It is found with the *Avicula contorta,* and the Fish- and Reptile-remains before alluded to, which represent the Bone-bed stage. The *Ostrea interstriata* is one of the characteristic shells of the "White Lias" zone, and furnishes an additional reason for including it with the Rhætic beds.

The *Avicula contorta* zone, from whence the other organic remains were obtained, will be recognized in the Beer-Crowcombe section as the "Flinty bed," No. 81. It is composed of a dense, light-blue stone, 1 foot in thickness, with alternating shelly layers,—the shells being in most beautiful condition; and in this they differ from those found in almost every other locality in this country, as also from those on the Continent. Dr. Wright has given a list of species (at p. 385) from Beer-Crowcombe. He supposes (p. 377) that the shells of this zone represent both the Kössen (or Rhætic) and also the Upper St. Cassian beds. For some time I held this view; but, on comparing the series I had made with that from the latter formation in the British Museum, I was surprised by not finding a single species in common; and I have since learnt that these stages have a fauna quite distinct, and that the species found in the *Avicula contorta* zone and the Bone-bed in this country are identical only with those of the Rhætic beds of the Continent, none of them being found in the St. Cassian beds below.

Notes on the Fossils.

It has been previously remarked that I have not observed the Bone-bed at Beer-Crowcombe; but a few fish-remains are found in the *Avicula contorta* zone, which are common to the Bone-bed when it is found in other localities. In the thin band of blue marl in the section at Vallis, fish- and reptile-remains are more abundant than at Beer-Crowcombe; but a detailed notice of these will be reserved for a general paper on that district. I shall then be able to show that the genera and species from the *Avicula contorta* zone at Beer-Crowcombe are common to the same zone at Vallis, and also to the Rhætic Mammalian Drift near Frome. It is important to recognize their presence in this zone at Beer-Crowcombe, as they will assist to determine the ages of the beds from whence that drift has been derived, and therefore the probable age of the oldest known Mammalia of England.

Sargodon tomicus. Pl. XV. fig. 1.

Sargodon tomicus, Quenstedt; Der Jura, tab. 2. figs. 34, 35.

A tooth, with a black, enamelled, semitransparent, canine-looking crown, the inner side of which is concave, the outer slightly convex and surmounted by a straight, sharp cutting-edge, in the largest specimens two lines across. In the worn specimens the centre of the crown is hollowed, usually with a slight sinus, dividing it into two equal parts. A very young, unworn tooth from Frome shows the crown in that stage to have been surmounted by three raised cusps of equal size. Below the crown, which occupies about a sixth of the height of the tooth, there is a long, slender, cylindrical, hollow shaft, showing in some specimens a slight tendency at the base to a fang-like division. They vary from 8 lines to 2 lines in length; breadth $\frac{1}{2}$ a line to 2 lines. One example only has been found in the "Flinty bed" of Beer-Crowcombe; from the Mammal-drift near Frome I have many examples. It is interesting to find that similar teeth were found by Pleininger with the *Microlestes antiquus* at Wirtemberg, and that they should in this country be found in the same association. The generic designation of the teeth above noticed is from the existing genus *Sargus*, which possesses somewhat imilar incisor-like teeth*.

SQUALORAIA, Riley & Stutchbury.

Four fish-vertebræ belonging to this genus have been found in the "Flinty bed" at Beer-Crowcombe. These also occur in the Frome Mammal-drift, where they are abundant.

There are also teeth of *Lepidotus*, *Saurichthys acuminatus*, *S. apicalis*, *Acrodus minimus*, and scales of *Gyrolepis*, all of which are found at Frome, and also a few undetermined fragmentary bones.

Mollusca.

DISCINA TOWNSHENDI, Davidson.

In a paper on some new secondary *Brachiopoda*, in the 'Geologist' for March last, I mentioned the occurrence of this rare species in the "Flinty bed" at Beer-Crowcombe, from whence I have but one example. It is the only Brachiopod that has yet been noticed from beds of the Rhætic formation, *in situ*, in this country, though I have *Lingula*, *Spirifer*, *Terebratula*, and *Rhynchonella* from the Frome drift. *Terebratula*, *Rhynchonella*, &c. are not uncommon in the Rhætic beds on the Continent; and Professor Suess informs me he has found the *Discina Townshendi* in Austria.

AVICULA CONTORTA, Portlock. Pl. XV. fig. 10.

The abundance and persistence of this shell has suggested the distinguishing name for the beds in which it occurs. It is commonly found in all the localities in which the zone is exposed. In most cases the beds yielding it are coarse and friable, when the shells are either fragmentary or rarely in good condition. The shells figured from the Rhætic beds on the Continent are usually from beds of sandstones, in which their casts only are preserved, which renders their specific comparison with the sharply defined shells from Beer-Crowcombe somewhat difficult.

The *Avicula contorta* from the latter place shows some variation, the curved longitudinal ribs being much stronger and more interrupted in some specimens than in others. I have also found the shell in the thin band of clay resting on the Carboniferous Limestone in the Vallis section, and also in the Bone-bed drift of the same locality.

AVICULA SOLITARIA, Moore. Pl. XV. fig. 11.

Shell convex, oblique, inequivalve, with eight regular radiating costæ passing from a very narrow convex umbone to the inferior margin; anterior auricle small; posterior auricle extended, ornamented with very fine striæ, and reaching to the inferior frontal margin.

* The figures given by Quenstedt in 'Der Jura,' tab. 2. fig. 36–38, probably belong to *Lepidotus*, and not to the genus *Sargodon*.

Only one example of this shell has been found. It is readily distinguished from the *A. contorta* by its more produced posterior auricle, by its less angular posterior side, by the costæ being much fewer in number, and by its narrower contour. Height 9 lines; width 6 lines.

Loc. The "Flinty bed," Beer-Crowcombe.

PLACUNOPSIS ALPINA. Pl. XVI. figs. 4, 5.

Anomia alpina, Winkler, Schicht. der Avic. contorta, pl. 1. fig. 1.
Anomia? Quenstedt, Der Jura, tab. 1. fig. 16.

Shell smooth, roundly ovate or orbicular, convex, variable; umbo with very slight ear-like expansion on the posterior side; ventral margin and sides regularly rounded. Smaller valve flattened or concave, rounded, closely fitting.

This shell appears to be identical with that figured by Quenstedt above, which he doubtfully refers to *Anomia*. It is common in the "Flinty bed" at Beer-Crowcombe, where species are found from 2 to 12 lines in length. In its more perfect state, when the shell has the test preserved, the exterior is quite smooth; but when this has been removed, the under surface exhibits, by aid of the lens, numerous close-set longitudinal striæ, which characterize the genus *Placunopsis*, to which it therefore seems more nearly allied.

GERVILLIA PRÆCURSOR. Pl. XV. figs. 6, 7.

Gervillia præcursor, Quenstedt, Der Jura, tab. 1. figs. 8–11.

Shell smooth, oblique, elongated, convex; hinge-line straight, produced posteriorly, bounded by a slightly raised horizontal rim; umbones rather prominent, anterior; ventral margin rounded; posterior inferior margin angular. Right valve flatter than the left; lines of growth distinct. The original pink colour of this shell is shown by six or seven broadish longitudinal lines in two examples in my possession.

Loc. From the "Flinty bed" of Beer, where it is somewhat rare.

GERVILLIA ORNATA, Moore. Pl. XV. fig. 8.

Shell small, convex, elongated, tapering gradually to the apex; hinge-line long, depressed, and slightly concave; the dorsal surface possesses six or seven longitudinal ribs, which commence from the umbo, and are extended to the ventral margin. These, as well as the flattened area, are crossed by numerous lines of growth, and give the shell a richly ornamented appearance.

Loc. This shell is associated with the *Gervillia præcursor* in the "Flinty bed" at Beer. Three specimens only of the left valve are known.

Length 4 lines; breadth 2 lines.

LIMA PRÆCURSOR. Pl. XV. fig. 9.

Lima præcursor, Quenstedt, Der Jura, pl. 1. fig. 22–24.

Shell inequilateral, moderately convex, front rounded, apex narrow;

dorsal surface covered with very narrow, close-set, wavy striæ, slightly diverging outwardly, between which there are a multitude of minute regular depressions.

The original figures given by Quenstedt appear to be casts; so that close comparison is impossible. He intimates the possibility of these Rhætic shells being the precursors of the *Lima gigantea* of the Lias; but the Beer shells show the ornamentation of their surfaces to be different, and the *Lima præcursor* to be a good species. In the *L. gigantea*, the longitudinal striæ are broader and more uncertain in their width than in the above shell, and the striæ are crossed by innumerable concentric raised lines, which are wanting in the *L. præcursor*.

When the test is perfect, this shell is nearly smooth (the ornamentation only becoming visible on the worn specimens from the "Flinty bed" of Beer). It attains larger dimensions than the original figures. Largest specimens, length 17 lines; breadth 12 lines.

Ostrea interstriata. Pl. XV. fig. 25.

Plicatula interstriata, Emmerich.

This is one of the most abundant shells in the Rhætic formation. It characterizes the "Ostrea-bed" of the "White Lias" in the sections given by Dr. Wright, at Garden Cliff, Wainlode Cliff, and in Warwickshire. It occurs in the "White Lias" of the West of England, and is also especially abundant, both in the Vallis clay-bed, and in the Mammal-drift near Frome. It is one of the most characteristic fossils of certain of the Continental Rhætic zones.

Ostrea fimbriata, Moore. Pl. XVI. fig. 24.

A species of *Ostrea* with a fimbriated margin is associated with the *O. interstriata* in the blue clay-band at Vallis. It attains much larger dimensions than the foregoing, but has hitherto only been found in fragments.

Pecten Valoniensis, Defrance. Pl. XVI. fig. 6.

This shell occurs in the Rhætic beds in most localities. I have obtained it from the "White Lias" of Stoke St. Mary; in the *Avicula contorta* zone at Uphill; and in the blue clay-band at Vallis. It is usually in fragments or much crushed. Fragments are also found in the Mammal-bearing drift of the same neighbourhood.

Arca Lycettii, Moore. Pl. XVI. fig. 7.

Shell subrhomboidal, convex; umbones anterior, slightly depressed; dorsal surfaces of the valves in the young shell with fine close-set striæ, which in the adult are nearly obliterated by acute concentric or transverse lines of growth, leaving the longitudinal striæ scarcely perceptible, except on the ventral margin and anterior end; anterior side most convex, and rounding to the edge; posterior end depressed, and separated from the side of the shell by an elevated indented rib, below which are three or four acute, indented, spreading costæ. The young shell possesses a sinus, commencing under the umbo and widening to the ventral margin, which in the adult is less marked.

Obs. The area and the hinge-line of this beautiful species are not clear of the matrix. It is very rare, and single valves only are found. It is named after my friend Dr. Lycett, of Scarborough.

Loc. From the "Flinty bed" of Beer-Crowcombe. Professor Suess has informed me that a somewhat similar shell is found in Rhætic beds at Hirtemberg, south of Vienna.

Axinus, Sowerby.

Shells of this genus occur in the greatest abundance on the surfaces of shelly layers of the "Flinty bed" at Beer-Crowcombe. They present considerable variety; so that were we disposed to multiply *species*, many might be created. We propose, however, giving four well marked forms, though probably even these may not be distinct species, as passages between them might be established.

Few shells have been subject to greater transposition, or have been placed under so many different genera, as those included in the group under notice. Von Credner in 'Leonard und Bronn's Jahrbuch' 1860, p. 307, remarks that one of the Rhætic species has by Roemer been called *Venus liassica*, but without a figure; by Quenstedt in 'Der Jura,' *Opis cloacinus*; that Escher notices it, but without naming it, from the Kössen beds; by Oppel and Suess it is called *Schizodus cloacinus*; and that it had previously been given by Bornemann, but without a figure, as *Tæniodon Ewaldi* of Dunker.

In previous notices of the fossils from this zone, by Mr. Strickland, the Rev. P. B. Brodie, and Dr. Wright, reference is made to a shell called *Pullastra arenicola*, Strickl., which is said to occur very abundantly, but only in casts, and of which no figure has been given: there is no doubt it belongs to the group under consideration. Similar shells have also been included by other English authors under the genera of *Tellinites, Isocardia, Cucullæa, Donax, Sedgwickia,* and *Schizodus*.

It is not clear wherein the following shells from Beer differ from the *Axinus* of Sowerby; and his name, having priority, is therefore retained.

Axinus cloacinus. Pl. XV. fig. 16.

Opis cloacinus, Quenstedt, Der Jura, tab. 1. fig. 35.

Shell triangular, quite smooth or with very delicate transverse striæ, broader than long, convex; umbones slightly anterior; anterior end rounded; posterior end slightly extended, divided from the dorsal surface by a depressed ridge running from the umbo to the posterior ventral margin; beyond this ridge is an obtuse angulated area.

This is the most abundant of this group of shells, and its characters appear to be persistent. It is more equilateral than the other forms accompanying it, and answers to the figure given of *Opis cloacinus* in Quenstedt's 'Der Jura'*. In the best-preserved specimens

* This shell also resembles the *Myophoria* of Merian in Escher's Vorarlb. Pl. iv. fig. 42.

the exterior is covered with a bluish or cream-coloured enamelled surface, the transverse striæ being exhibited only on the more worn examples. Width 7 lines; length 5 lines.

Locality. The "Flinty bed" of Beer-Crowcombe.

Axinus depressus, Moore. Pl. XV. fig. 17.

Shell flattened, convex, transversely oval, nearly smooth or with distant transverse lines of growth, inequilateral; umbones depressed, slightly anterior; posterior and anterior ends towards the ventral margin somewhat rounded.

This shell is much flatter than the *A. cloacinus,* and its form generally more rounded; and, whilst the latter possesses a decided posterior ridge and acute area, in the *A. depressus* they are more rudimentary, or with but a slight thinning out of the valve towards the posterior edge. Length $5\frac{1}{2}$ lines; breadth 9 lines.

Axinus concentricus, Moore. Pl. XV. fig. 19-21.

Shell rather small, transverse, ovate, flattened, inequilateral; umbones convex, anterior; posterior end produced, with a slight ridge and flattened area, which commence from the umbo; ventral margin and anterior side rounded; dorsal surface with numerous regular or widely separated concentric lines of growth, which obliquely cross the area.

Quenstedt, in 'Der Jura,' tab. 1., gives some bivalves of uncertain forms. His figures 28 & 30 in all probability represent the above species.

Locality. It is common in the "Flinty bed" of Beer. Largest example, length 4 lines; breadth 5 lines.

Axinus elongatus, Moore. Pl. XV. fig. 18.

Shell originally smooth, equivalve, inequilateral, convex; umbones anterior; dorsal surface covered with very fine, close-set, regular, transverse striæ; anterior side rounded; posterior side flattened and produced, and tapering to the ventral surface.

This shell is to be distinguished from those previously described by its more transverse elongation, by the finer and more regular striæ on its surface, and by its being more inequilateral. Two examples only of this genus, belonging to the above species, with both valves, are in my possession. Height 3 lines; breadth 5 lines.

Locality. From the "Flinty bed" of Beer-Crowcombe.

Pleurophorus elongatus, Moore. Pl. XV. figs. 14, 15.

Shell ovately oblong, depressed, most convex at the umbones, which are very anterior; anterior end roundly tapering, posterior end flattened, angular; from the umbones a ridge crosses the valve to the posterior ventral end, behind which is an angulated area; a second more depressed ridge separates this from a lengthened flattened dorsal margin. The front of the shell possesses lines of growth, which cross the ridges at right angles, and return obliquely on the dorsal side towards the umbones.

Examples in our possession present considerable variety, depending on the more or less worn condition of the test. In some the lines are very acute, whilst in others the shell has a much smoother surface.

Under the name of *Cypricardia Suevica*, a shell is figured by Oppel and Suess in "Kössener Schichten," table 1, fig. 4, from Nürtingen, which, though apparently distinct from our species, probably belongs to the same genus.

Hitherto the genus has not been recognized higher than the Permian beds.

Locality. The "Flinty bed" of Beer-Crowcombe. Perfect specimens are rare. Length of largest examples 18 lines; depth 7 lines.

Pleuroporus angulatus, Moore. Pl. XV. figs. 12, 13.

Shell rather small, inequivalve; umbones small, depressed, anterior; anterior end angular; posterior end deepest, flattened, and slightly angular; dorsal surface of perfect shell quite smooth, crossed by three acute, slightly curved ribs passing from the umbones to the posterior ventral margin.

This species is rare. It may readily be distinguished from the *P. elongatus* by its very obtuse form, and by its generally smoother surface. Length 8 lines; depth 4½.

Locality. The "Flinty bed," Beer-Crowcombe.

Cardium Rhæticum. Pl. XV. fig. 28.

Cardium Rhaticum, Merian, Escher's Vorarlb. pl. 6. fig. 40, 41.

Shell nearly smooth, globose, convex, nearly equilateral; umbones prominent, beak recurved; posterior and anterior sides rounded; ventral margin round and slightly extended; posterior end with numerous depressed longitudinal ribs; dorsal surface either quite smooth or crossed by very numerous faint concentric striæ, which decussate the longitudinal ribs on the posterior side.

This shell appears to have been quite smooth in its more perfect condition, and only shows the striæ on its dorsal surface in specimens that are more or less worn. Length 7 lines; breadth 8 lines.

Locality.—The "Flinty bed" of Beer, where it is somewhat rare.

Leda Titei, Moore. Pl. XV. fig. 25.

Shell oblong, equivalve, rather inequilateral, convex, inflated, thick; umbones closely incurved over a concave oblong area; margins of the valves close-set and smooth; ventral margin and anterior side rounded; posterior end produced; exterior of the valves covered with very fine, regular, concentric, transverse striæ.

I have but one example of the above shell; but this is fortunately in very good condition, and is one of only three instances from Beer in which both valves of the shell are attached. Oppel and Suess in "Kössener Schichten," tab. 2. fig. 9, have given a shell under the name of *Leda Deffneri* (the *Leda alpina* in Winkler, pl. 1. fig. 8). The shell figured by these authors differs materially from the *Leda Titei*. The umbones of the former are more anterior; the posterior side is angular and more attenuated; and the concentric striations altogether differ. Indeed, as far as I can judge by the figures of these authors, their shells represent, not the genus *Leda*, but that variety of the *Axinus* which I have given under the name of the *Axinus elongatus* (Pl. XV. fig. 20).

It is named after my friend Wm. Tite, Esq., M.P., F.R.S., F.G.S.

Locality. Beer-Crowcombe. Height $4\frac{1}{2}$ lines; breadth 8 lines.

Modiola minima, Sow. Pl. XV. figs. 26 & 27.

Mytilus minutus, Goldfuss, Petref. ii. p. 173, pl. 130, fig. 6.

Shell elliptical, convex, smooth or with concentric irregular striations; umbones thick and blunted, subterminal; hinge-line straightened; upper portion of the dorsal surface much convex, and flattening to the central margin, which is rounded.

This shell is one of the most abundant in the "Flinty bed" at Beer-Crowcombe, and is also common in the "White Lias" in many localities in the West of England. It is also one of the most characteristic shells of the Rhætic sandstones of Suevia. It presents considerable varieties in form, some being thinner and more elongated than others. In its young state it is very obtuse and convex. They occur at Beer from 2 lines in length by $1\frac{1}{2}$ line in height, to 20 lines in length, and 10 lines in height in adult examples.

Pteromya, Moore, 1861.

Shell oblong, thin, smooth, convex but depressed, inequivalve, inequilateral; umbones anterior, depressed, and curving to the anterior side; dorsal margin extended, slightly rounding or acute; ventral margin rounded; anterior side most convex; posterior side flattened, concave, curved, widely gaping. Dorsal surface covered with strong transverse concentric or wavy lines of growth, which on the right valve continue to the posterior edge. On the left valve these are interrupted on the posterior side by a ridge, passing from the umbo to the posterior ventral margin, beyond which the shell is extended into a flattened or concave winged area, with a rounded or angular margin at the ventral extremity.

We are not aware that the inequivalve character in the genus proposed above is so largely possessed by any other of the *Myadæ*, to which family it evidently belongs. All the shells in my possession are single valves, and none have the interior or the hinge exposed. For some time we were disposed to consider that valves having so different a character were to be referred to more than one species; and it was not until after an examination of many examples that a satisfactory determination was arrived at respecting them; it was then found in every instance that no right valve possessed the ridge and extended area, which are present invariably on the left. In other respects the valves are precisely similar.

PTEROMYA CROWCOMBEIA, Moore. Pl. XV. figs. 22 & 23.

Shell thin, smooth, inequilateral, inequivalve, ovately oblong, convex but depressed; anterior end most convex, rounded; posterior side depressed or slightly concave, rising again towards the edge, gaping; surface of the valves either nearly smooth or with waved transverse lines of growth, continued on the right valve to both extremities; posterior side of the left valve possesses a slightly curved depressed ridge, passing from the umbo to the ventral margin, beyond which the shell is extended into a winged, flattened or slightly concave area.

This shell is abundant; and in all the examples I have seen, the right valve is without the posterior ridges and area, which are invariably present on the left. Some of the shells have a grey enamelled exterior, in which state they are almost smooth. When this is abraded, the transverse striæ are most visible. Height 7 lines; breadth 12 lines.

Locality. The "Flinty bed" of Beer-Crowcombe.

PTEROMYA SIMPLEX, Moore. Pl. XV. fig. 24.

Shell nearly smooth, inequilateral, oblong, convex; posterior side flattened, ridge acute, anterior moderately convex; transverse lines of growth on dorsal surface.

This shell differs from the *P. Crowcombeia* in being more regularly convex, and in its straighter and more symmetrical form. Only the left valve of this species is known.

Locality. Found in the "Flinty bed" with the *P. Crowcombeia*, at Beer.

MYACITES STRIATO-GRANULATA, Moore. Pl. XVI. fig. 1.

Shell ovately oblong, twice as wide as long, inequilateral, convex; umbones rather anterior; anterior end slightly depressed, and side rounded; posterior side extended, graduating to a rounded edge; dorsal surface covered by a thin grey test, in which are situated innumerable minute rounded granulations, arranged in close-set longitudinal lines, most prominent on the anterior side; these are crossed, especially towards the ventral margin, by numerous fine transverse lines of growth.

Only one specimen of the above shell has been found. Width 20 lines; length 10 lines.

Locality. The "Flinty bed," Beer-Crowcombe.

Although it will be seen that there are several species of the family of *Myadæ* from the Beer bed, specimens are by no means numerous. When studying these shells it is of importance to attend to their external condition, without which specific forms might be multiplied. Were the thin outer integuments in the above shell abraded, its granulated character would disappear, leaving it either nearly smooth or exhibiting only its transverse lines of growth, such as are seen on the *Anatina præcursor*, Quenst. ('Der Jura,' pl. 1. fig. 32.) I am disposed to believe that if the latter shell, together with the *A. Suessii*, Oppel, found in the Rhætic beds, had possessed their tests, they would have to be removed from *Anatina* to *Myacites*. Both species are given below, but are not in a condition to establish this point.

Anatina ? præcursor, Quenstedt. Pl. XVI. fig. 3.

Shell transversely oblong, subtriangular or ovate, convex, inequilateral; anterior side rounded, depressed; posterior end extended; umbones rather anterior, depressed; transverse lines of growth on dorsal surface distinct, curving round a slight area on the posterior dorsal margin.

It is not improbable that this shell may hereafter be found to possess a granulated exterior; but the surface of the test is removed in the examples in my collection. As it does not possess the characters of the genus *Anatina*, and also differs in shape, it may have to be removed to *Myacites*. Width 14 lines; height 7 lines.

Locality. From the "Flinty bed" of Beer-Crowcombe.

Anatina ? Suessi, Oppel. Pl. XVI. fig. 2.

Shell ovately oblong, conical, twice as wide as long, inequilateral; umbones anterior, slightly depressed; anterior end rounded; posterior side flattened, edge rounded, slightly curving upwards; frontal margin of shell concave; a very slight ridge from the umbo crosses the shell obliquely, dividing it into two nearly equal portions. The surface is covered by concentric striations, which on the posterior side curve upwards.

This shell somewhat differs from the figure given by Dr. Oppel; but there cannot be a doubt that it belongs to the same species. That gentleman remarks that the species is found with the *Anatina præcursor* in the sandstone about 8 feet below the Bone-bed at Nürtingen. In my example the outer integument is removed; and therefore the precise character of the exterior may not be given in the figure. Like the last-named shell it may eventually have to be referred to *Myacites*. Width 16 lines; height 8 lines.

Locality. From the "Flinty bed" of Beer-Crowcombe.

Myophoria postera, Bronn. Pl. XVI. figs. 8–10.

Trigonia postera, Quenstedt.

Perfect shell quite smooth, trigonal, convex; anterior and ventral margins slightly rounded; umbones rather depressed, directed anteriorly; area broad, and often very acute, with about twenty longitudinally curved, somewhat variable costæ; dorsal surface smooth when perfect, when worn presenting numerous regular concentric transverse ribs, which in some examples cross the marginal carina, when it is distinctly denticulated. In the *left* valve the carina is distinct and single, either smooth or denticulated, and widening to the frontal margin. In the *right* valve the shell possesses two or more carinæ, separated by smooth longitudinal sulcations.

From the above remarks it will be seen that, like many others of the family, this shell presents considerable variety, which in this case does not appear to be due to age. Attention is also necessary to the condition in which the shells are found; for in many of the Beer specimens the outer surfaces of the shells are preserved. They are then seen to have perfectly smooth exteriors, whilst when this has been eroded or has perished the transverse striæ on the dorsal surfaces are perceptible. Without attention to this fact several species might be created from what are only varieties or different conditions of the same shell. The areas in the *M. postera* are much more acute in some examples than in others, but they all possess, though with some little modification, longitudinal striæ of the same general character. The transverse striæ on the dorsal surface amount to upwards of fifty in number. Height of shell 5 lines; breadth 5½ lines.

Locality. From the "Flinty bed" of Beer, where it is not uncommon.

Cerithium constrictum, Moore. Pl. XVI. fig. 13.

Shell small, narrow, elongated, tapering, apex rather obtuse; volutions six or seven, each ornamented with three prominent equidistant transverse ribs, volutions separated by a deep angular concavity.

Observations. This is a pretty and well-distinguished species. Between the ribs there are indications of slight longitudinal striæ. The aperture appears to have been rounded, but is imperfectly disclosed. It is very rare. Length 3 lines; width ¾ of a line.

Locality. The "Flinty bed" of Beer.

Cerithium decoratum, Moore. Pl. XVI. fig. 14.

Shell small, turreted, tapering, reticulated; volutions eight or nine, conical, with encircling prominent ribs; sutures concave, angular; oblique longitudinal striæ cross the ribs, and, passing into the angles of the sutures, give the shell a generally reticulated aspect.

Of this shell I have only two examples. Length 3 lines; breadth 1 line.

Locality. The "Flinty bed" of Beer.

Cerithium cylindricum, Moore. Pl. XVI. fig. 15.

Shell small, very slender, regularly tapering; volutions ten, ornamented with three transverse slightly oblique ribs, volutions rather distant, with a somewhat rounded concave suture.

This shell is very rare, and is to be distinguished from the *C. constrictum* by its more elongated and cylindrical form, the whorls increasing very slowly in size, and also by its less angular and rounded sutures. Length 2½ lines; width ½ a line.

Locality. The "Flinty bed" of Beer.

Cerithium Rhæticum, Moore. Pl. XVI. fig. 16.

Shell small, tapering; volutions seven or eight, flattened, with encircling striæ, the coarsest of which are situate over the sutures, which are slightly concave.

This shell differs from those previously described, by the more flattened surface of the whorls, which have a greater number of encircling ribs, and by its possessing one or more depressed ribs which pass into and divide the suture. Height 3 lines; breadth $\frac{3}{4}$ line.

Locality. The "Flinty bed" of Beer.

CYLINDRITES FUSIFORMIS, Moore. Pl. XVI. fig. 18.

Shell very small, smooth, apex acute, with four rather oblique volutions, the upper ones flattened; the last whorl more convex and ovate, and tapering at its base into an extended folded columella. Aperture longitudinally oval. Length $1\frac{1}{2}$ line; width $\frac{1}{2}$ line. Three specimens of this shell are in my cabinet from the "Flinty bed" of Beer.

All the species of this genus at Beer are very minute. Some casts of larger size have been found in the Rhætic beds of Suevia; and M. Merian mentions a species from the beds of Vorarlberg.

CYLINDRITES OVALIS, Moore. Pl. XVI. fig. 19.

Shell small, smooth, longitudinally ovate, apex acute; whorls five, regularly tapering and slightly convex, terminal whorl large and convex. A slight ridge encircles the upper portion of the whorl. Lines of growth are perceptible on the last volution. Aperture narrow at the top, but expanding at the base. Only one specimen of this shell is known. Length 4 lines; breadth 2 lines.

Locality. The "Flinty bed" at Beer.

CYLINDRITES ELONGATUS, Moore. Pl. XVI. fig. 20.

Shell smooth, elongate, cylindrical; whorls five, the upper convex, spiral, and divided by a narrow rounded suture. The terminal whorl is quite cylindrical and occupies nearly four-fifths of the entire length of the shell. Aperture not exposed.

Only one specimen of this species has yet been found. Its length is $2\frac{3}{4}$ lines; breadth 1 line. It appears very similar in form, though smaller, to a cast figured in 'Kössener Schichten' (tab. 1. fig. 1), by Oppel and Suess, under the name *Actæonina*, sp.

Locality. From the "Flinty bed" of Beer.

CYLINDRITES OVIFORMIS, Moore. Pl. XVI. fig. 21.

Shell very small, smooth, elongate, cylindrical; whorls four, with a very depressed spire; apex rather acute. The terminal whorl is cylindrical, occupying the greater length of the shell, and at its base is folded and slightly tapering.

This shell differs from the *C. elongatus* chiefly in the more depressed character of the upper whorls, and in its more tapering base. Length $2\frac{1}{2}$ lines, breadth 1 line. Aperture the length of the last whorl, and very narrow.

Locality. The "Flinty bed," Beer-Crowcombe.

CHEMNITZIA HENRICI? Pl. XVI. fig. 12.

Cerithium Henrici? (Martin), Mém. Soc. Géol., 2 sér. vol. vi. pl. 2. fig. 17, 18.

Shell small, tapering, thick; volutions six or seven, conical, narrow, with rather oblique or curved longitudinal prominent costæ; sutures slightly concave and rounded; aperture slightly extended.

I have but one adult example of this shell, and this has lost a small part of its apical portion. The terminal whorl is rather more conical and ovate, and its striæ, which are about sixteen in number, are less prominent than on the preceding whorls. This shell is in height 3 lines; in breadth 1 line. It is, with some doubt, referred to the *Cerithium Henrici* of Martin, though it seems rather thinner.

I am possessed of another very small Rissoa-looking shell with four whorls, which may probably be its younger form.

Locality. The "Flinty bed" at Beer.

Chemnitzia nitida, Moore. Pl. XVI. fig. 11.

Shell small, smooth, turreted, spire rather obtuse, with five slightly oblique, rounded or convex volutions, separated by a well-defined suture.

We have obtained only one example of this shell. Dunker figures a Rhætic shell under the name of *Paludina solidula*, which appears to be similar to it. Unfortunately, as is the case with most of the Rhætic shells from Beer, the aperture is not exposed, and therefore does not help to a generic determination; but, as the whorls of the above shell on close examination present a tendency to be slightly costated, we are induced to place it under the above genus. Length $2\frac{1}{2}$ lines; breadth 1 line.

Locality. The "Flinty bed," Beer.

Natica Oppelii, Moore. Pl. XVI. fig. 17.

Shell small, smooth, glossy, globose; whorls four, convex; spire depressed; apex acute; the last whorl much increased in size, and showing lines of growth; umbilicus small; aperture large, ovate.

This is the only Natica yet found in this zone in England. It probably represents a cast given by Oppel and Suess in 'Kössener Schichten,' tab. 1. figs. 3*a*, 3*b*, and also by Quenstedt in 'Der Jura,' tab. 1. figs. 17–20, though our shell does not attain so large a size. The former authors give figures of a still larger species, which, from the casts, must have possessed more angular volutions. *Natica alpina*, Merian, is also from Rhætic beds, but is different from our shell. It is the most common Gasteropod in the "Flinty bed" at Beer-Crowcombe, and is named after my friend Dr. Oppel of Munich.

Trochus Waltonii, Moore. Pl. XVI. fig. 23.

Shell small, conical, obtuse; whorls four or five, flattened or slightly convex, covered with very fine transverse striæ; aperture oblique, depressed; umbilicus small; base flattened or slightly concave, with five encircling striæ.

In its young state this shell is abundant; but the more adult forms are not so. When young it is more depressed, and the striæ are more strongly marked.

The species, from the "Flinty bed" at Beer, is named after my friend Wm. Walton, Esq. of Bath.

Trochus nudus, Moore. Pl. XVI. fig. 22.

Shell small, conical, quite smooth, striæ obtuse; volutions four or five, slightly oblique, smooth, separated by a slightly oblique rounded suture; base smooth, moderately concave; mouth depressed, oblique.

This species is found with the *T. Waltonii*, but is more rare, and is well distinguished from it by the above characters.

Locality. The "Flinty bed," at Beer.

Straparolus Suessii, Moore. Pl. XIV. figs. 2–5.

Shell small, discoidal, depressed, thickest at the back; whorls flattening towards the umbilicus, and increasing very slowly without change of form or ornamentation, the last whorl possessing about sixteen tubercles situate close upon the back, each continuing into a broad depressed rib, terminating in a small lengthened tubercle over the umbilicus, with slight concave depressions between the ribs. By aid of the lens very fine striæ may be discovered which are crossed by equally fine longitudinal lines, giving the shell a slightly reticulated aspect. Under side somewhat concave, with ornamentation less defined. Back of the shell flattened, with three equally raised ridges, situate between two lateral, less elevated tubercular ridges; between the ridges are four smooth longitudinal grooves.

I was at first disposed to consider this little shell an Ammonite; but, as a trifling difference is apparent on the sides, and also a very slight concavity on the under side, this is rendered doubtful. With some hesitation it is placed under the above genus. Only one specimen has hitherto been obtained. It is named after my esteemed friend Professor E. Suess, of the Imperial Museum of Vienna, who has given much attention to the fauna of the Rhætic Beds.

Height of the shell 4 lines; width 5 lines.

Loc. The "Flinty bed," Beer-Crowcombe.

Chiton Rhæticus, Moore. Pl. XVI. figs. 28, 29.

Plate small, smooth, elongately ovate, rounded; umbo elevated, with a broad sinus; lateral areas extended and depressed, with irregular concentric lines of growth.

Numerous valves or plates of the above little species occur in the blue clay-bed at Vallis. The largest example measures $3\frac{1}{2}$ lines in breadth by 2 lines in depth.

Zoophyton.

Montlivaltia.

This genus is represented in the "Flinty bed" at Beer by a single specimen. It has been placed in the hands of Mr. Tomes for description in his paper on new Liassic Zoophytes. He reports to me respecting it, that it is "a horizontal section, near to the calices, probably of some species of *Montlivaltia*. The septa are remarkably thin, and their sides appear to be without tubercles. Fine cycla are traceable, none of which appear to have met in the centre; and hence it is probable that in this species there was no spurious columella, which is so often seen in this genus. It must, however, be remembered that this may depend in some measure upon the age of the specimen."

Echinodermata.

Numerous fragmentary remains of this family, chiefly spines, are to be found in the "White Lias" of Stoke, &c., on the surface of the "Flinty bed" at Beer, and in the blue clay at Vallis. Dr. Wright enumerates four species from the "White Lias" of Pinhay Bay—viz. *Cidaris Edwardsii*, Wright, *Pseudo-diadema lobatum*, Wright, *Hemipedina Bechei*, Broderip, *H. Bowerbankii*, Wright,—which, if from the true "White Lias," we should consider Rhætic species.

Ophiura?

A single joint found in the clay-band at Vallis appears to have represented this or an allied genus in the Rhætic age.

Encrinite.

Joints of a very small Encrinite are not uncommon in the blue marl at Vallis.

Cirriped.

Pollicipes Rhæticus, Moore. Pl. XVI. fig. 30.

Valves small, enamelled, elongated, triangular, pointed at the upper end; an elevated central ridge divides the valves longitudinally, on either side of which are very fine longitudinal striæ, which are crossed by transverse lines of growth, giving the valve a richly ornamented appearance. Length $1\frac{1}{2}$ line; breadth $1\frac{1}{2}$.

Though generally imperfect, the shell is not uncommon in the blue clay resting upon the Carboniferous Limestone in the Vallis section. It is at present the oldest known representative of the family *Cirripedia.*

Entomostraca.

Cypris liassica (?), Brodie.

The upper surfaces of the blocks of "White Lias" in the sections near Taunton are frequently covered with the shells of this little Crustacean. The same conditions prevailed when the "Flinty bed" at Beer-Crowcombe was deposited, as the shells are very numerous on its weathered surface. In the Vallis section it is very rare, and only represented by a single specimen attached to a fragment of *Lima præcursor.*

Estheria minuta, Alberti, sp.

Posidonomya minuta, Auct.

At the Vallis, near Frome, a few specimens of this little crustacean occur in a cream-coloured limestone, and also in the conglomerate.

Plants.

Naiadita acuminata (?), Buckman, Geol. Cheltenham, p. 93.

Two little groups of Plants, apparently identical with the above, have been found in the thin layers of stone interposed between the Conglomerate and the Inferior Oolite at Vallis, associated with examples of *Estheria* and Insects.

The stone is concretionary, and lithologically similar to the "White Lias," or to the "Landscape-stone;" and I am therefore disposed to consider it to be on the same horizon as the Cypris- and Plant-bed of the Rev. P. B. Brodie, noticed in his work on Fossil Insects. The conglomerate separates it from the band of blue clay containing the *Avicula contorta,* and the fish- and other remains previously noticed.

Carabidæ.

A few wings of Coleopterous insects occurring with the *Estheria* and Plants previously mentioned, appear closely allied to the *Carabidæ.*

It will be seen, from the foregoing organic remains, that the beds we propose including in the Rhætic formation, embracing the "White Lias" and those which in this country are between it and the Keuper Sandstones, yield an interesting and peculiar fauna, differing in its general facies from that found in the Lower Lias above, and entirely from that in the Keuper Sandstones below; whilst it also differs from that in the St. Cassian stage, which follows the Rhætic formation on the Continent.

On another occasion I hope to be able to make important additions to the Mammalia, Reptilia, and Fishes of this zone; but, without including these families, I have shown that the Mollusca, Crustacea, &c. amount to at least fifty-two species,—some of the genera, such as *Chiton, Pollicipes,* and *Pteromya,* being recognized in it for the first time; and this list I have no doubt may be increased hereafter.

Dr. Oppel, in 'Kössener Schichten,' states that, on the whole, but twenty-five species have been found in this zone abroad. Of these, fourteen species at most are all we are enabled to identify with British species.

Table of British "Rhætic" Fossils, from the Avicula contorta *zone, noticed in this Paper.*

Genera and Species.	Authority.	Reference.	Locality.
MAMMALE.			
Microlestes antiquus	Plieninger		Holwell.
PISCES.			
Sargodon tomicus	Quenstedt	Pl. XV. fig. 1.	Beer, Holwell.
Squaloraia	Riley & St.		Beer, Vallis, Holwell.
Lepidotus, teeth of			Beer, Vallis, Holwell.
Saurichthys acuminatus	Agassiz		Beer, Holwell.
—— apicalis	Agassiz		Beer, Vallis, Holwell.
Acrodus minimus	Agassiz		Beer, Vallis, Holwell.
Gyrolepis, scales of			Beer, Vallis, Holwell.
MOLLUSCA.			
Avicula contorta	Portlock	Pl. XV. fig. 10.	Beer, Vallis, &c. &c.
—— solitaria	Moore	Pl. XV. fig. 11.	Beer.
Anatina præcursor	Quenstedt	Pl. XVI. fig. 3.	Beer.
—— Suessii	Oppel	Pl. XVI. fig. 2.	Beer.
Arca Lycettii	Moore	Pl. XVI. fig. 7.	Beer.
Axinus cloacinus	Oppel & S.	Pl. XV. fig. 16.	Beer.
—— depressus	Moore	Pl. XV. fig. 17.	Beer.
—— concentricus	Moore	Pl. XV. figs. 19–21.	Beer.
—— elongatus	Moore	Pl. XV. fig. 18.	Beer.
Cardium Rhæticum	Merian	Pl. XV. fig. 28.	Beer.

Table of British "Rhætic" Fossils, from the Avicula contorta zone (continued).

Genera and Species.	Authority.	Reference.	Locality.
MOLLUSCA.			
Discina Townshendii	Davidson...	....	Beer.
Gervillia præcursor	Quenstedt .	Pl. XV. figs. 6, 7.	Beer.
—— ornata	Moore	Pl. XV. fig. 8.	Beer.
Lima præcursor	Quenstedt .	Pl. XV. fig. 9.	Beer.
Leda Titei	Moore	Pl. XV. fig. 25.	Beer.
Modiola minima	Sowerby ...	Pl. XV. figs. 26, 27.	Beer, &c.
Myacites striato-granulata .	Moore	Pl. XVI. fig. 1.	Beer.
Myophoria postera	Quenstedt .	Pl. XVI. figs. 8–10.	Beer.
Ostrea fimbriata	Moore	Pl. XVI. fig. 24.	Vallis.
—— interstriata	Emmerich .	Pl. XVI. fig. 25.	Vallis, Stoke, &c. &c.
Pleurophorus angulatus ...	Moore	Pl. XV. figs. 12, 13.	Beer.
—— elongatus	Moore	Pl. XV. figs. 14, 15.	Beer.
Placunopsis alpina	Winkler ...	Pl. XVI. figs. 4, 5.	Beer.
Pteromya Crowcombeia ...	Moore... ...	Pl. XV. figs. 22, 23.	Beer.
—— simplex	Moore	Pl. XV. fig. 24.	Beer. [&c.
Pecten Valoniensis	Defrance ...	Pl. XVI. fig. 6.	Vallis, Uphill, Stoke,
Bivalves, uncertain	....	Pl. XVI. figs. 26, 27.	Beer.
Straparolus Suessii	Moore	Pl. XV. figs. 2–5.	Beer.
Trochus nudus	Moore	Pl. XVI. fig. 22.	Beer.
—— Waltonii	Moore	Pl. XVI. fig. 23.	Beer.
Chemnitzia nitida............	Moore	Pl. XVI. fig. 11.	Beer.
Cerithium Henrici ?	Martin ...	Pl. XVI. fig. 12.	Beer.
—— constrictum	Moore	Pl. XVI. fig. 13.	Beer.
—— decoratum...............	Moore	Pl. XVI. fig. 14.	Beer.
—— cylindricum	Moore	Pl. XVI. fig. 15.	Beer.
—— Rhæticum...............	Moore	Pl. XVI. fig. 16.	Beer.
Chiton Rhæticus	Moore	Pl. XVI. figs. 28, 29.	Vallis.
Cylindrites fusiformis	Moore	Pl. XVI. fig. 18.	Beer.
—— ovalis.....................	Moore	Pl. XVI. fig. 19.	Beer.
—— elongatus	Moore	Pl. XVI. fig. 20.	Beer.
—— oviformis	Moore	Pl. XVI. fig. 21.	Beer.
Natica Oppelii	Moore	Pl. XVI. fig. 17.	Beer.
PLANTA.			
Naiadita acuminata	Buckman .	....	Vallis.
CRUSTACEA.			
Cypris liassica	Brodie	....	Beer, Stoke, Vallis, &c.
Estheria minuta	Alberti......	....	Vallis.
CIRRIPEDON.			
Pollicipes Rhæticus	Moore	Pl. XVI. fig. 31.	Vallis.
ECHINODERMATA.			
Echini, spines, &c.	....	....	Vallis, Stoke, Beer, &c.
Ophiura ?, joints of	....	....	Vallis.
Encrinites, stems of	....	....	Vallis.
ZOOPHYTUM.			
Montlivaltia	....	....	Beer.
INSECTA.			
Carabidæ ? wings of	....	....	Vallis.
ANNELIDE.			
Serpula, traces of	....	....	Beer.

Appendix.

Section at Shepton-Mallet.—Whilst this paper has been going through the press, I have made an excursion along the unfinished line of Railway from Shepton-Mallet to Wells. In doing this I was much gratified to find that an admirable section of the Rhætic beds has been opened up, in which all the strata from the Red Keuper Marls to the *Ammonites Bucklandi* beds are exposed. There is probably no other section in this country in which continuously, and at one view, these zones of rock can be so well studied; and fortunately there is every probability that the sides of the railway-cutting at this point will always remain open. The section given below is about a mile west of Shepton-Mallet; the beds have a gradual dip to the east towards that town.

Section at Shepton-Mallet (in ascending order).

	ft.	in.		ft.	in.
1. Red Keuper Marl	10	0	14. Blue stone	0	10
2. Yellowish sand	1	0	15. Blue stone	0	9
3. Green sandstone	1	3	16. Clay	0	1
4. Clay	0	2	17. Stone	0	4
5. Green sandstone	2	0	18. Dense black clay	12	0
6. Green sandstone	2	6	19. Flinty bed	1	0
7. Clay	0	4	20. Blue clay	2	6
8. Yellowish sandstone	0	9	21. "White Lias;" about twenty beds; passing upwards into thin and somewhat irregular beds representing the Saurian and other zones at Beer-Crowcombe and Street.		
9. Clay	0	2			
10. Yellowish sandstone	0	6			
11. Greenish clay	0	5			
12. Yellow sandstone	1	0			
13. Blue clay	1	0			

The sandstones Nos. 3 to 14, which are superimposed upon the Red Marls, would yield very excellent building-stone, could they be extracted over any considerable area. They are apparently destitute of organic remains, though they contain the black vegetable-like patches noticed in the same zone at Beer-Crowcombe: what these are derived from, it is difficult to conjecture.

No. 18 is a black laminated clay, 12 feet in thickness, full of the impressions of Rhætic shells. The *Avicula contorta* is very abundant, and attains double the size of our figured specimen. *Axinus, Cardium, Myacites,* and other genera are also present.

No. 19, which rests immediately upon the above, is the equivalent of the "Flinty Bed" of Beer-Crowcombe. Its lithological appearance is precisely similar; but, although it contains many organic remains, they are in so comminuted a state that very few are to be extracted entire. On its outer surface are a few scales and teeth of Fishes of the age of the Bone-bed, which, as at Beer-Crowcombe, is entirely wanting, as a distinct bed, in this section, though it is to be found in other places near Shepton-Mallet.

The blue clay, No. 20, I was unable to examine for organic remains. The "White Lias," and the beds passing upwards, are not so well represented as in other sections in the West of England, the beds being thinner, more irregular, and without the clay-partings present in the latter sections.

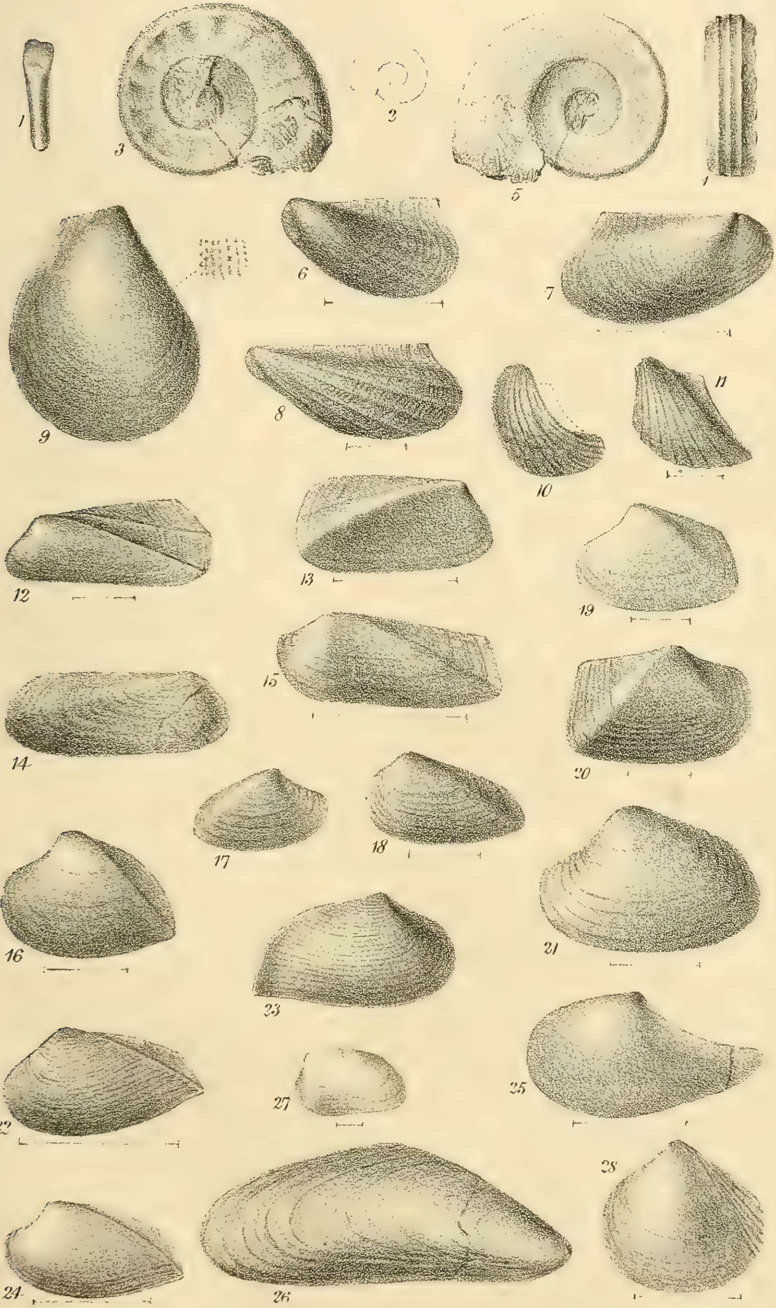
EXPLANATION OF PLATES XV. & XVI.

PLATE XV.

Fig. 1. Sargodon tomicus, *Quenstedt*, nat. size. Beer.
2. Straparolus Suessii, *Moore*, natural size. Beer.
3. „ „ upper surface, enlarged.
4. „ „ back view, enlarged.
5. „ „ under surface, enlarged.
6. Gervillia præcursor, *Quenstedt*, right valve, showing lines of original colour. Beer.
7. Gervillia præcursor, left valve. Beer.
8. —— ornata, *Moore*, enlarged. Beer.
9. Lima præcursor, *Quenstedt*, nat. size. Beer.
10. Avicula contorta, *Portlock*, nat. size. Beer.
11. „ solitaria, *Moore*, enlarged. Beer.
12. Pleurophorus angulatus, *Moore*, enlarged. Beer.
13. „ „ left valve; worn. Beer.
14. —— elongatus, *Moore*, nat. size. Beer.
15. „ „ right valve; nat. size. Beer.
16. Axinus cloacinus, *Quenstedt*, enlarged. Beer.
17. —— depressus, *Moore*, nat. size. Beer.
18. —— elongatus, *Moore*, enlarged. Beer.
19. —— concentricus, *Moore*, left valve, enlarged. Beer.
20. „ „ right valve, enlarged. Beer.
21. „ „ variety, enlarged. Beer.
22. Pteromya Crowcombeia, *Moore*, left valve, nat. size. Beer.
23. „ „ right valve, nat. size. Beer.
24. —— simplex, *Moore*, left valve, nat. size. Beer.
25. Leda Titei, *Moore*, perfect shell, slightly enlarged. Beer.
26. Modiola minima, *Sowerby*, nat. size. Beer.
27. „ „ (?) young, enlarged. Beer.
28. Cardium Rhæticum, *Merian*, nat. size. Beer.

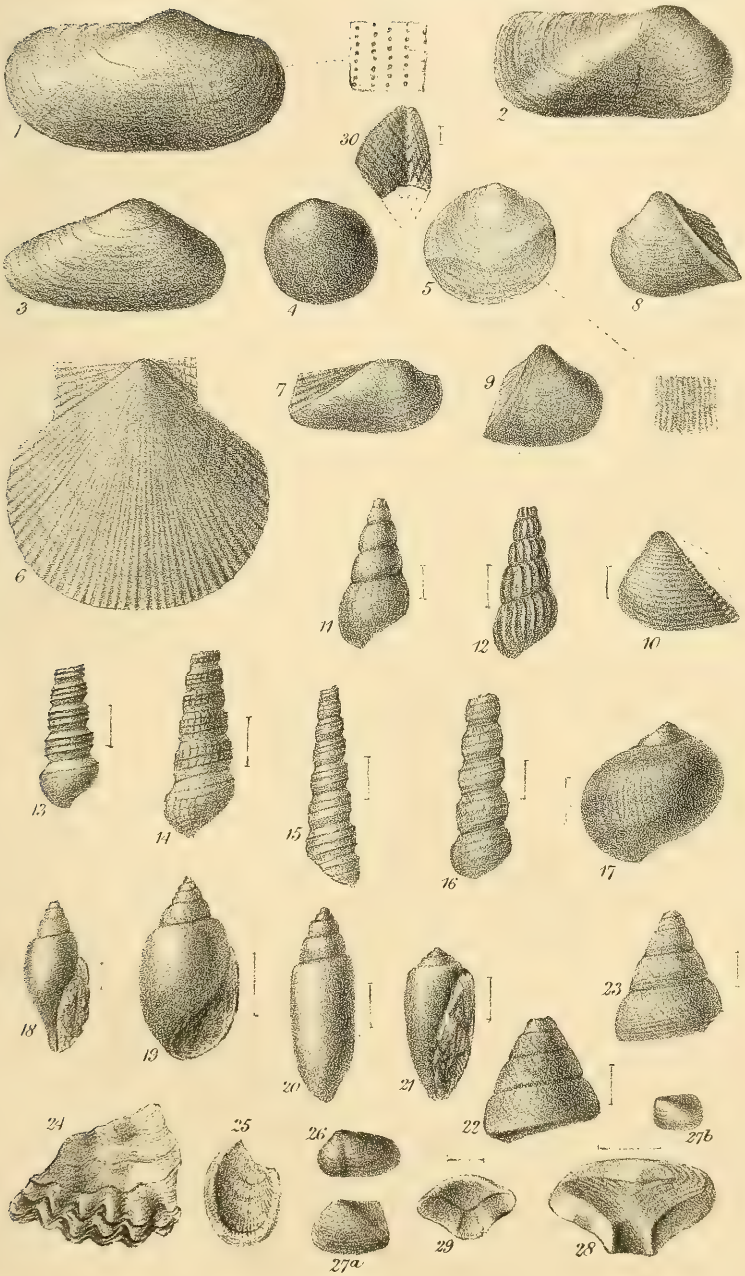
PLATE XVI.

Fig. 1. Myacites striato-granulata, *Moore*, showing the granulated surface, nat. size. Beer.
2. Anatina? Suessi, *Oppel*, nat. size. Beer.
3. —— ? præcursor, *Quenstedt*, nat. size. Beer.
4. Placunopsis alpina, *Winkler*, large valve, nat. size. Beer.
5. „ „ exterior of small valve, nat. size. Beer.
6. Pecten Valoniensis, *Defrance*, nat. size.
7. Arca Lycettii, *Moore*, nat. size. Beer.
8. Myophoria postera, *Quenst.*, right valve, enlarged. Beer.
9. „ „ left valve.
10. „ „ left valve, showing denticulated carina.
11. Chemnitzia nitida, *Moore*, enlarged. Beer.
12. —— Henrici, *Martin*, enlarged. Beer.
13. Cerithium constrictum, *Moore*, enlarged. Beer.
14. —— decoratum, *Moore*, enlarged. Beer.
15. —— cylindricum, *Moore*, enlarged. Beer.
16. —— Rhæticum, *Moore*, enlarged. Beer.
17. Natica Oppelii, *Moore*, enlarged. Beer.
18. Cylindrites fusiformis, *Moore*, enlarged. Beer.
19. —— ovalis, *Moore*, enlarged. Beer.
20. —— elongatus, *Moore*, enlarged. Beer.
21. —— oviformis, *Moore*, enlarged. Beer.
22. Trochus nudus, *Moore*, enlarged. Beer.
23. —— Waltoni, *Moore*, enlarged. Beer.
24. Ostrea fimbriata, *Moore*, nat. size. Vallis.
25. —— interstriata, *Emmerich*, nat. size. Vallis.
26. Bivalve, uncertain, nat. size. Beer.
27. „ „ nat. size. Beer.
28. Chiton Rhæticus, *Moore*, single plate, enlarged. Vallis.
29. „ „ interior, enlarged. Vallis.
30. Pollicipes Rhæticus, *Moore*, enlarged. Vallis.



Geo West lith. W West imp

RHÆTIC FOSSILS.



Geo. West lith W. West imp

RHÆTIC FOSSILS.

June 5, 1861.

Joseph Tolson White, Esq., Mining Engineer, Wakefield, Yorkshire, and William Boyd Dawkins, Esq., B.A., Jesus College, Oxford, were elected Fellows.

The following communications were read:—

1. *On the Occurrence of Large* Granite Boulders, *at a Great Depth, in* West Rosewarne Mine, Gwinear, Cornwall. By H. C. Salmon, Esq., F.G.S.

At West Rosewarne Mine, in the parish of Gwinear, Cornwall, some remarkable granite-boulders have been met with in the 50-fathom level below the adit; the adit being 24 fathoms deep from surface, this 50-fathom level is consequently 74 fathoms from surface.

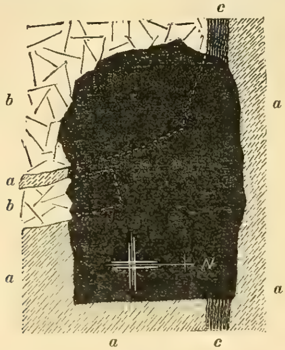
The sections given in the accompanying figs. 1, 2, 3, show the form and position of these boulders in the level. Their full size cannot be ascertained, for they extend, as will be seen, into the roof and south side of the level; but, taking those parts which are exposed, there appear to be two large boulders, about 4 inches apart, the eastern one projecting down 3 feet into the level, and the western one projecting down 2 feet, as shown in the vertical section, fig. 2. The length and width of these in the back of the level are shown in the section (horizontal), fig. 3. The length of the eastern boulder is 4 feet 2 inches, and that of the western boulder 3 feet 10 inches: the width which they extend across the back of the level, from the south side, is the same for both, viz. 2 feet 9 inches. The particular form of these boulders, and their relative position to each other, are fully shown in the sections; the vertical transverse section in fig. 1. across the great eastern boulder, shows the manner in which it, and a smaller granite mass beneath it, originally penetrated across the level—the dotted lines marking the portions removed in excavating the level.

Besides these two large boulders, there are also five other smaller granite boulders or pebbles found in their neighbourhood. The dimensions of the sections of these latter which appear in the south side of the level are—(1.) 14 inches by 5½ inches; (2.) 22 inches by 12 inches; (3.) 11 inches by 8 inches; (4.) 4 inches diameter; (5.) 7 inches by 3 inches; all shown in fig. 2, in the order given, from west to east. It is worthy of remark that the two first-named—one lying 2 inches under the great eastern boulder, and the other lying a little to the west of this, just under the point of contact of the two large boulders—are more angular in form than either of the two large boulders themselves, or either of the three remaining smaller ones. Although the full size of the large boulders cannot be ascertained, their probable size, judging from the portions exposed, would appear to be nearly the same; that is, about 6 feet in width and depth, with a length of from 4 feet to 4½ feet.

The locality where these boulders are found is shown by the drawing* No. II. The West Rosewarne Mine is supposed to be worked

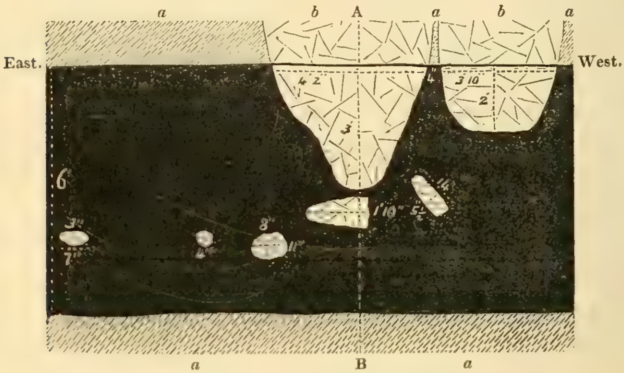
* Not engraved with this paper.

Fig. 1.—*Vertical Section across the Level at the line* AB *in fig.* 2, *showing the original projection of the Boulders across the Level or Gallery.*



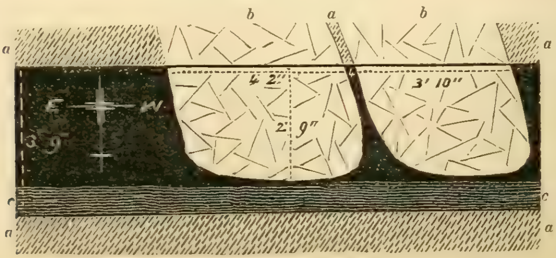
a, *a*. Killas. *b*, *b*. Granite-boulders. *c*, *c*. Lode.

Fig. 2.—*Vertical Section along the side of the Level, showing the Granite-boulders on the South.*



a, *a*. Killas. *b*, *b*. Granite-boulders.

Fig. 3.—*Horizontal Section, or Ground-plan, showing the Boulders in the Back of the Level.*



a, *a*. Killas. *b*, *b*. Granite-boulders. *c*, *c*. Lode.

on the same lode as that wrought on in the Rosewarne United Mines lying to the east, on the other side of the road. The direction of this lode, which is about due east and west, extends east towards the main granite-range of Crowan, which is about two miles distant from West Rosewarne. In this mine, the direction of this main lode is thrown out of its ordinary direction by taking a bend to the left. At the point where (going west) this bend commences, a branch-lode goes off with the same direction as the normal bearing of the main lode: this lode is called the "north branch;" and it is on the south side of this, lying in the "killas" or "country," that the boulders are found. The sections given in figs. 1 and 3 accurately show the position of the boulders with regard to this branch-lode, which is here from 10 to 12 inches wide, the latter width being the maximum of the lode as far as it has been seen in the ground opened. Both the large boulders abut up close against the lode, but do not extend into it.

I have said that the boulders are in the "country" or "killas," which is so far correct that a defined line can be drawn between the lode and the strata in which the boulders are imbedded. But although this line can be drawn, there is yet a very striking analogy between the two. The lode is almost entirely made up of breccia (principally angular fragments of killas); and the "country" in which the boulders occur is also itself of a brecciated and conglomeratic character, containing numerous small boulders and pebbles of capel and porphyry (elvan): they range from $\frac{1}{2}$ inch, or even less, up to 12 inches in diameter, and are called by the miners "bullies," the small ones being called "young bullies," and the larger ones "grown bullies." As a general rule, these rounded pebbles and boulders seem to be found in the "country" in the neighbourhood of the lode, but *not* generally in the lode itself, nor in the "country" at any distance from the lode. In none of the cross-cuts entirely away from the lode, in what miners would call "clean-country," are any of these boulders to be seen. Thus the lodes themselves seem to be essentially breccia, rarely containing round boulders or pebbles. The "country" in the immediate neighbourhood of the lode is also brecciated, but in a minor degree to the lode itself, and is eminently characterized by these rounded boulders and pebbles; while the "country" at a distance from the lodes is generally quite free from either breccia or pebbles, which, as far as can be seen, seem to die out gradually, and not to cease at any definite line. These facts seem to me to prove satisfactorily that there is a decided relation between the lodes and these breccia and boulder-characteristics of the "country," which it should be our object to investigate much more thoroughly and carefully than has hitherto been done; for, although similar phenomena have been frequently observed in other mines in the same district, they seem to have been rather regarded as matters of curiosity than investigated as facts which might help to elucidate the conditions under which the lodes originated.

At Relistian Mine, west of West Rosewarne, and probably on the same run of lodes, and at Herland Mine, to the north-west, on parallel lodes, the occurrence of boulders and pebbles has long been noticed and recorded, particularly in the 'Transactions of the Royal Geological Society of Cornwall,' which contain several references to them. In vol. iii., in a paper "on the Granite of the western part of Cornwall," p. 238, the late Mr. Carne thus refers to the pebbles at Relistian:—

"The pebbles of the Relistian Mine are well known: here, at a depth of 100 fathoms below the surface (which is not higher than the surrounding country), a mass of pebbles was discovered in the tin-vein, about 12 ft. in length, and nearly the same in width and thickness; and scattered pebbles were found in the vein far beyond those boundaries. The pebbles are slate,—the same as the slate of the country, which appears to have some chlorite in its composition,—and are cemented together by a chloritic substance. In the crevices between the pebbles, and connected with the cementing substance, are oxide of tin and yellow sulphuret of copper; the former always crystallized; the latter, never."

In vol. v. p. 36, Mr. William Jory Henwood thus describes similar phenomena in the same mine and in Herland:—

"At Relistian the slate contains numerous spheroidal concretions; some of them are compact, others schistose slate, and others are entirely of quartz. In Herland, about 110 fathoms deep, there are numerous nodular masses of granite, which consist of a base of felspar with some quartz and a little mica; they are fine-grained and decomposing. They vary in size; and whilst some are not larger than a hazel-nut, others are two or three feet in diameter. Both at Relistian and Herland they are entirely enveloped by the slate, and have no apparent connexion with each other; neither have the masses of granite in the latter any contact with the lodes, or with any of the small strings of quartz traversing the slate."

In Table 36 of the same vol. v., referring to the 155-fathom level in Relistian, Mr. Henwood makes the following note:—

"On both sides of the lode. but particularly on the north, the slate is very soft, and opens in small joints: in this, round masses of slate are often firmly imbedded. They are surrounded on all sides by slate; but this structure, which prevails in many parts of the rock, is only visible on breaking it. . . . . I was shown one round stone of elvan which was said to have been found at 135 fathoms deep."

As far as I can ascertain, however, nothing as yet has been found at such a depth, at all comparable, either in size or character, with the boulders I have described. The largest referred to are stated as from 2 to 3 feet in diameter, while those I have described must be at least 6 feet in diameter. The mineral character also is decidedly different; for the granite of the pebbles and boulders hitherto found seems to have been invariably of a porphyritic character, with crystals of felspar and quartz crystallized out of a base (probably felspathic), and with very little mica. Boulders of this class have also been found in West Rosewarne, east of the cross-cut, in the fifty-fathom level at the point marked *b*, and in the seventy-fathom level at the point marked *c*, in the drawing No. II. Specimens of these are on the table; and an inspection of them will show their marked porphyritic character. On the other hand, the composition of the two large boulders, and of the two smaller and more angular fragments beneath them, is such as is essentially characteristic of a large granite-mass, there being an entire absence of any porphyritic characteristics, and an abundant development of mica. Now, the smaller porphyry-granite boulders are, most probably, true granite, and derived from a large granite-mass; but another hypothesis, which should assume for them a derivation from some of the numerous elvan-courses which traverse this district, would not be absolutely inconsistent with the evidence of origin afforded by their mineral character; for elvan-courses do at times (particularly at considerable depths) take an approximate porphyry-granite structure, and show some mica: in their case, consequently, it would not be absolutely necessary to assume their introduction from the surface; they might have been introduced at considerable depths, and become rounded in the lodes or broken country adjoining them. But in the case of these large boulders, such a solution is scarcely conceivable. Their distinctive mineral character places it beyond doubt that they are derived from a large granite-mass; and the distance of the nearest granite from the locality where they are found seems to preclude any hypothesis except that which would assume their introduction to have taken place, by a fissure, from the surface. I leave out of the question the hypothesis that these boulders can be considered as being contemporaneous with the original deposition of the strata; for it appears to me that their evident correlation with the other boulders and pebbles (which, although not necessarily, nor, indeed, usually found in the lodes themselves, have yet been recognized by long experience as having an undoubted, although ill-understood connexion with them), taken in connexion with the brecciated and conglomeratic nature of the country in which they are imbedded, renders any such suggestion quite untenable. The whole bearing of the evidence shows that the boulders must be taken as having been subsequently introduced, and most probably by a fissure from the surface.

Still, a solution of this kind presents some peculiar theoretical difficulties. The only plausible hypothesis of the formation of metalliferous deposits such as those of Cornwall—the only one capable of giving even an intelligible explanation of their phenomena—is that which assumes them to be, like granite and some other crystalline rocks, of an essentially *hypogene* origin,—to have necessarily originated at considerable depths, and become subsequently exposed by the action of denudation. But if these boulders were introduced from the surface, the lode must be of a date subsequent to the uncovering of the neighbouring granite-range by the action of denudation, and be held to have become opened and filled comparatively near the then surface, instead of being *hypogene*—of having originated at great depths.

In searching for an elucidation of the obscure and complicated causes under which metalliferous lodes have originated, nothing is more important than to endeavour to ascertain what periods of time had elapsed between their formation and that of the eruptive rocks with which they are generally associated, and which they usually penetrate. Merely to ascertain, as we have already done, that the lodes are generally subsequent in age to these rocks, is of comparatively little practical value; what we want to know is, were they immediately subsequent, almost contemporaneous?—or did long intervals of time elapse between the formation of the one and the other? Another important consideration is, to ascertain at what depth beneath the surface—under what amount of cover—did they originate.

Anything that can throw light on these subjects is of the highest geological importance. It seems to me that these boulder-phenomena of Gwinear may have that result; but at any rate they are of great interest as affording evidence of the physical conditions attending the formation of, at least a certain class of, metalliferous lodes.

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2. *On an* ERECT SIGILLARIA *from the* SOUTH JOGGINS, NOVA SCOTIA. By J. W. DAWSON, LL.D., F.G.S.

(Abridged.)

THE erect trees so frequent in this celebrated coast-section, though often distinctly ribbed, rarely show the minute markings of the leaf-scars in a sufficiently perfect state to enable them to be compared with those of the flattened trunks seen in the shales and ironstones. This, no doubt, arises in part from the circumstance that the bases of the trunks of *Sigillariæ* did not always retain their characteristic markings, and in part from the unfavourable influence of an erect position in coarse and often laminated sediment. The specimen, to which this note relates, and which I obtained in 1859 from a sandstone in Group XIV. of my section of the South Joggins*, affords an exception to the generally imperfect condition of these trunks sufficiently remarkable to merit a short notice.

The specimen measures 3 feet in height, and is $10\frac{1}{4}$ inches in diameter at the base, 9 inches in the middle, and $7\frac{1}{2}$ inches at the top, where it was abruptly broken off. At the base it shows the usual tendency to divide into four main roots; but these have been nipped off or flattened by pressure, not having been filled with sediment. The trunk retains its form on one side, but on the other the bark has been rent from top to bottom, and in part folded inward. This seems to have been caused by the pressure of the surrounding sediment, and has probably somewhat diminished the diameter of the stem. The interior of the trunk is filled with grey sandstone, similar to that of the enclosing bed. The outer bark, less than a line in thickness, is in the state of bituminous coal; and an internal cast with a thin coaly envelope represents the pith. This internal cast extends through the greater part of the length, but has fallen to one side. It is only half an inch in diameter. The coaly matter remaining on its surface shows, when prepared with nitric acid,

* Quart. Journ. Geol. Soc. vol. x. p. 6.

cellular structure; and traces of transverse Sternbergian markings remain in parts of it, so that it must not be regarded as the *woody axis*, which has disappeared, but merely as the *pith-cylinder*.

The leaf-scars and other surface-markings are preserved throughout the specimen, but only in a few places in sufficient perfection to show the more minute features of the former. At the upper part the ribs are very prominent, and there are twenty-six in the whole circumference, the breadth of each rib being about nine-tenths of an inch. On the outer or cortical surface each rib is flattened, or even concave, along the middle, and strongly rounded at the sides, descending into deep intercostal furrows; the flat mesial portion being smooth, the lateral portions marked with sharp vertical ridges, and in places with very delicate longitudinal and transverse striæ. The leaf-scars extend across the smooth middle portion of the rib, and are distant from each other one inch vertically. In form they resemble those of *Sigillaria transversalis*, *S. Defrancii*, and *S. Brochantii*, Brongt., being transversely lanceolate, emarginate above, with acute lateral edges. Those best displayed show two vascular punctures, with a third mark or prominence between and rather below them. On the so-called ligneous surface, or that of the inner bark, the ribs are slightly furrowed or striated lengthwise; and the leaf-scars are represented by two deep punctures of the vascular scars.

In tracing the ribs downward, some of them wedge out and disappear; so that at the middle of the length of the trunk there may be about 22; each with a breadth increased to one inch and four-tenths, and flatter than those at the top, with the intercostal furrow shallower. The leaf-scars are now widened transversely, and have lost their minute markings on the cortical surface; while on the ligneous surface the vascular punctures are twice as far apart as at the top. About the middle the vertical distance of the scars diminishes somewhat suddenly to seven-tenths of an inch.

In the lower third of the stem the ribs are quite obliterated, and the whole surface is wrinkled with coarse waving striæ or small furrows, due apparently to the expansion of the outer bark. The leaf-scars still remain in regular vertical rows; but these are reduced to about twelve, and apparently at the base to as few as nine. The vertical distance of the scars is still about 0·7 inch; but the transverse distance between the centres of the rows is increased to 2·8 inches or more. In form the leaf-scars are now transverse furrows, an inch or more in length, and the vascular punctures are half an inch or more apart in each scar.

Of the roots I could obtain no specimens; but the markings on the bark at the base of the trunk are precisely similar to those on many Stigmarian roots found attached to less perfectly preserved stems, and a few stigmaroid areoles are perceptible on the lower surface of the stump.

The woody axis has entirely disappeared, nor does any mineral charcoal appear in the base of the cast. It has either been entirely removed by decay, or has been washed out by the waves before the hollow bark was filled up.

As this trunk appears to belong to a species not previously described, and we have a better knowledge of its parts and mode of growth than of those of most of the named species, I may propose for it a specific appellation, and would call it *Sigillaria Brownii* in commemoration of the many interesting discoveries in relation to these plants made by my friend Richard Brown, Esq., of Sydney, Cape Breton.

The author adds to this notice some remarks on points relating to *Sigillariæ* in general, illustrated by the specimen above-described:—1. The evidence of the exogenous growth of *Sigillaria* *. 2. The decadence of the leaves from the lower part of the trunk in the living state, and their abundance (as *Cyperites*), detached, in the coal-measures: the shorter vertical distance of the scars on the lower part of the trunk, showing that, when young, the leaves were much more crowded than subsequently: the absence of transverse bands of deformed and crowded scars sometimes seen on *Sigillariæ* †, probably connected with periods of fructification, and possibly occurring on the upper part of the trunk only. 3. The difficulty of comparing the characters of erect with those of prostrate *Sigillariæ*. 4. The species of *Sigillaria* found at the Joggins may amount to about twenty; and with reference merely to the habit of growth, without regard to the resemblances or differences in the leaf-scars, these may be arranged in three groups. The first will include the present species with *S. reniformis*, *S. alternans*, *S. organum*, and another (*S. ovalis*, mihi) with oral scars like those of *S. catenulata* but an inch apart vertically. These have broad and well-marked ribs, attain to a large size, and often occur erect. Other species with narrow and less distinct ribs and more or less crowded scars, as *S. elegans*, *S. Knorrii*, *S. scutellata*, *S. Saullii*, &c., do not appear to have attained to so great diameter, and are more rarely seen erect. In some of these species the markings and leaf-scars seem to be more perfectly preserved to the very base of the trunk than in the species before mentioned. A third group consists of species like *S. Defrancii*, *S. Menardi*, &c., which are destitute of ribs and have the scars arranged spirally. Some of these were of considerable diameter, others quite small; but they are rare, and I have not recognized them in the erect position. 5. The bast-like tissue of the inner bark of *Sigillariæ* is abundant in some of the coal of the Joggins; whilst the discigerous tissue ‡ is prevalent in the great Pictou coal-seam: the author thinks that in the former case the decomposition of the vegetable matter was probably subaërial, or like that of a forest-soil; whilst the conditions of the latter were those of peaty bogs.

A *résumé* of the observations previously published regarding *Sigillaria*, by Brongniart, Corda, and others, is added in the supplemental note to this paper.

* Quart. Journ. Geol. Soc. vol. x. p. 32.
† Ibid. vol. xv. p. 640.
‡ Ibid. vol. xii. p. 631.

3. *Note on a* Carpolite *from the* Coal-Formation *of* Cape Breton. By Dr. J. W. Dawson, F.G.S.

All the best authorities on coal-plants are disposed to refer the seeds or fruits known by the generic names *Trigonocarpum* and *Rhabdocarpus* to phænogams, and probably to gymnosperms. In this case they may have belonged to *Coniferæ* or *Sigillariæ*, or to both. That they belonged in great part to the latter is, I think, rendered probable by their occurrence very abundantly in the middle part of the coal-measures where *Sigillariæ* abound, by their various forms corresponding rather to the many species of *Sigillariæ* than to the few of Conifers, and by their abundant occurrence in the interior of hollow stumps of *Sigillariæ* and in the surrounding beds. Still these fruits or seeds may have belonged to very different plants; and, as an example of the type of structure most frequently associated with *Sigillariæ*, I have prepared a short notice of a species of which very well-preserved specimens exist in my collection, and to which I have assigned the name of

Trigonocarpum Hookeri. Figs. 1–5, page 526.

Numerous specimens of this species occur in a thin calcareous layer in the coal-measures near Port Hood, Cape Breton. They are not compressed, and are fossilized by calc-spar and iron-pyrites. Their form is ovate,—the length being 0·3 inch, and the breadth 0·2 inch. The external surface is rough and destitute of distinct markings. Internally they present the following structures:—1. An outer coat (*testa*), which is thick, carbonaceous, and apparently of a dense cellular structure. This corresponds to the outer supposed "fleshy coat" of Lindley and Hooker; but in this species I think it must have been firm and hard, like the outer coat of the seeds of pines, which it much resembles in appearance and structure. 2. An inner coat (*tegmen* or *embryo-sac*), which is thin and marked on its outer surface with interrupted ridges, almost precisely in the manner of the corresponding coat in the seed of *Pinus pinea*. This coat is often pyritical, and in some specimens it presents toward the smaller end indications of three ridges. It corresponds, no doubt, to the outer coat of the ordinary *Trigonocarpa*. 3. A nucleus occupying the whole interior of the last-mentioned coat, and exhibiting at the smaller end certain wrinkles and a projecting tubercle, marking the position of the embryo and micropyle. When the seed is sliced longitudinally, the nucleus is seen to present an outer thick layer of calc-spar, stained by vegetable matter, and an inner mass which is colourless. In the smaller end, toward the micropyle, the remains of the embryo and its suspensor are seen replaced by iron-pyrites, in the manner represented in fig. 3. In some specimens the outer coat appears as if divided into two layers, and the nucleus has shrunk inward from the inner coat, presenting two additional surfaces, which may represent original lines of structure, but are, perhaps, results of decay. A very similar species, which occurs in vast abundance in the interior of an erect *Sigillaria* at the Joggins, has the

Figs. 1 to 5.—Trigonocarpum Hookeri, *Dawson, from the Coal-measures of Cape Breton.*

Fig. 1.

Fig. 2.

Fig. 3.

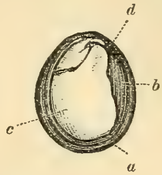

Fig. 5.

Fig. 4.

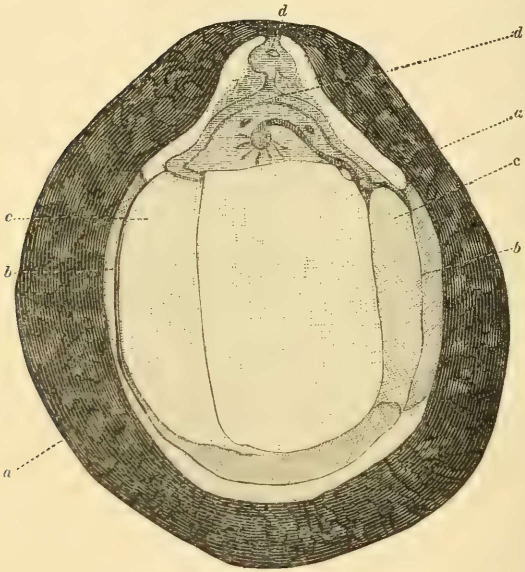

Fig. 1. Perfect specimen, natural size.
Fig. 2. Specimen deprived of its outer coating.
Fig. 3. Broken specimen magnified.
Fig. 4. Section magnified: *a*, the testa; *b*, the tegmen; *c*, the nucleus; and *d*, the embryo.
Fig. 5. Portion of the surface of the inner coat more highly magnified.

outer coating very dense and coaly, and with a transverse fibrous structure. In some specimens it shows a projecting ridge on each side, and longitudinal striæ, which might entitle it to be placed in the genus *Rhabdocarpus*; but no coal-fossils are more deceptive than these carpolites, which, when flattened or deprived of their outer coats, present appearances very dissimilar from those of the perfect condition.

I am by no means certain that this note adds much to the knowledge already possessed of the structure of *Trigonocarpum*; but it affords an additional example, and this of a species similar to those most frequently associated with remains of *Sigillariæ*.

4. *On a* Reconstructed Bed *on the top of the* Chalk *and underlying the* Woolwich *and* Reading Beds. By William Whitaker, B.A., F.G.S., of the Geological Survey of Great Britain.

In a memoir illustrating Sheet 13 of the Map of the Geological Survey of Great Britain (p. 21), I have noticed the fact that "at Maidenhatch Farm, between Bradfield and Pangbourn" (over six miles west of Reading), "there is a chalk-pit showing above 20 feet of rubbly chalk, with scattered blocks of chalk and irregular lines of flint, overlying ordinary chalk. A similar bed of apparently reconstructed chalk may be seen in a pit to the south of Tilehurst" (over two miles a little south of west of Reading), "where it is capped by the bottom-bed of the Reading Beds, so that the reconstruction must have taken place before the deposition of the latter formation."

I have since seen a like bed, a short distance below the point where the Chalk is capped by the Tertiary beds, in a pit by Batten's Barn, a mile north of Burnham, near Maidenhead. There was here "about 18 feet of reconstructed chalk, with scattered flints and blocks of chalk, and a line of flints near the middle. There were some pipes of the drift-clay with flints, so common in chalk-countries, in the top of this bed*." This section and the one near Tilehurst are clearly at the very top of the Chalk; but the one at Maidenhatch Farm is on the flank of a valley cut through that rock.

In the neighbourhood of the Bedwins (in Wiltshire), near Marlborough Forest (in Sheet 14 of the Map of the Geological Survey of Great Britain), there may be seen in many places, close by the junction of the Tertiary beds (of which there are outliers in that part) and the Chalk, a bed which seems to be made of reconstructed chalk, and consists of pale-bluish and almost white clay, very chalky, and containing small pieces of chalk, overlain by a confused mass of pieces of hardened (? silicified) and somewhat flaggy chalk. This latter is locally known as "*roach*" (= rock); the fragments composing it are as hard and tough as most crystalline limestones, and I saw nothing at all like them in the chalk of the neighbourhood.

In making some deep drains down the hill-slope on the south of Stoke Farm, west of Great Bedwin, this bed was found just at the junction of the Chalk and the Woolwich and Reading Beds. I was too late, however, to see whether it passed under the latter.

Just by the brick-yard, about three-quarters of a mile to the east of the same village, there is much of this "roach" and the accompanying chalky clay, here again close by the junction of the Tertiary beds with the Chalk: "roach" also occurs in the fields around, just below the spots where the former come on.

Now this common occurrence of a reconstructed bed close by the junction of the two formations, and there only, naturally leads one to infer that it stretches beneath the later of them, the Woolwich and Reading Beds. That a bed of a like nature is elsewhere found

* From the MS. of a memoir illustrating Sheet 7 of the Map of the Geological Survey.

beneath that formation has been before shown; and there can therefore be no reason why such should not also be the case near Great Bedwin.

It is clear (even from the section near Tilehurst alone) that, whilst in most places the Woolwich and Reading Beds rest on an undisturbed surface of the Chalk (as may be well seen at Castle Kiln, Reading, at the kiln north-east of Theale*, and at Shaw Kiln, Newbury†), in others the latter formation has not only been denuded (as we know it to have been from other reasons), but also redeposited, in a somewhat confused state, before the deposition of the former.

Whether a like bed occurs anywhere beneath the Thanet Sand I know not. It is possible that the deposition of the reconstructed bed near Tilehurst, &c., may have gone on at the same time as that of this formation further to the east; both agree in occurring between the Chalk and the bottom-bed of the Woolwich and Reading Beds.

I should add that the reconstruction above-noted is not the same as that, of a later date, by which a gravel-like mass of pieces of chalk and flints (with here and there a flint-pebble) has been formed at the lower parts of some of the larger chalk-valleys, at the junction of the Low-level Gravel and the Chalk; nor is it to be confounded with the rubbly or flaggy structure that the Chalk often has near the surface, and which is caused, I take it, by atmospheric action alone.

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5. *On some of the* Higher Crustacea *from the* British Coal-measures. By J. W. Salter, F.G.S., of the Geological Survey of Great Britain.

It is almost as satisfactory to clear up the history of a little-known or doubtful fossil as to discover one perfectly new. In the present case we have both pleasures combined; for the new and very perfect Macrurous Crustacean here for the first time given from the coal-measures illustrates and explains some published fragments, the real nature of which ought not to have been so long misunderstood.

In Prestwich's great paper on the Coalbrook-dale Coal-field, read in 1836, and published‡ some time after, a dubious Crustacean carapace, very imperfect in some respects, was introduced in the same plate § with the *Limuli*. It is said, in the Explanation of the Plates, that "the only living form to which Dr. Milne-Edwards could refer it is the *Apus cancriformis* of the rivers of Central and Southern Europe." It was called therefore *Apus dubius*. The figure is more imperfect than it need to have been; for the internal cast of the carapace only is figured, and Mr. Prestwich's collection contains the other half of the nodule, a gutta-percha cast from which shows the true external surface; and from this our figure 6 is drawn, only the other

* See Geological Survey Memoir illustrating Sheet 13, pp. 38 & 39.

† *Ibid.* Sheet 12. Now in the press.

‡ Transact. Geol. Soc., 2nd ser. vol. v. p. 413.

§ *Op. cit.* pl. 41. fig. 9.

way upwards. The serrated border and the interrupted central ridge are very clearly shown in both specimens and figures.

Again, in a paper in the Society's Journal* "on some Crustaceous Remains in Carboniferous Rocks," there is a short notice of some specimens (or, rather, good electrotype copper moulds of the specimens) presented to the Society by W. Ick, Esq., F.G.S. These were from the white-ironstone-measures of Ridgeacre Colliery.

One of these specimens was certainly anything but an *Eryon*, to which Dr. Ick at first thought of referring it; and better materials have enabled Prof. Huxley to describe it as a Schizopod or Stomapod Crustacean of singular form, under the name of *Pygocephalus Cooperi*†. The other was a fine carapace (fig. 7), evidently identical with Prestwich's *Apus dubius*, and was referred to by myself in Morris's 'Catalogue,' 2nd edit. 1854, as the remains of a Macrurous Crustacean. I had then only just established the identity of the two fragments. A more complete figure was afterwards given in Lyell's 'Manual of Elem. Geology,' 5th edit. 1855, p. 388, under the temporary name *Glyphæa*, to which genus, however, it is not very nearly allied.

And now we have the entire form of a kindred species. This most precious fragment (fig. 1) was brought to my notice by Dr. Rankine, of Glasgow. It is in the cabinet of W. Grossart, Esq., of Salsburgh, by Holytown, who has liberally sent the rarity to London for examination; and I learn from Dr. Rankine that its place is in the true coal-measures, above the uppermost *limestones*, and 960 feet below the "Ell-coal"—in the band of ironstone termed the "slaty black-band."

I will give the characters of this more perfect species first; and, as the genus is not to be confounded with any of the Liassic or Oolitic ones published by Von Meyer, Münster, &c., I shall propose the name *Anthrapalæmon*‡ for it. It is broader than the general form of the *Astacidæ*, or than *Glyphæa* and its Liassic allies, but much narrower than *Eryon*.

ANTHRAPALÆMON, gen. nov.

Carapace scarcely so broad as long (except when crushed flat), simple, flatter than semicylindrical, the sides a little arched outwards. A strong central ridge in front, projecting as a thick (serrate?) spine, is separated by a concave space, or slight furrow, from a posterior central ridge which only occupies (in the type-species, *A. Grossarti*) a small portion of the length. Front margin serrate. The outer antennæ have wide, square basal joints, apparently *without any advantage*; the 2nd and 3rd joints not much oblique; the rest about as broad as long. Abdomen as broad as long, of six joints (besides the telson), broad and very short; the pleuræ, except the 2nd, pointed. Telson very broad; appendages to the penultimate joint double on each side, subtrigonal, broad.

* Vol. i. p. 199, 1844.

† Quart. Journ. Geol. Soc. vol. xiii. p. 336, pl. 13.

‡ From ἄνθραξ, coal, and *palæmon*, a prawn. The name has only a general signification, and is not intended to indicate a real relation to *Palæmon*.

Subgenus Palæocarabus. Type—*Anthrapalæmon dubius,* Prestw.

Carapace rectangular-oblong, serrate in front and along the sides, with a faint cervical furrow at the anterior third. Rostrum strong, projecting; posterior ridge prominent, complete to the hinder margin, separated abruptly from the rostrum by the transverse furrow.

I have purposely restricted the characters of *Anthrapalæmon* proper, because I think that the *A. dubius* may very probably turn out to be a distinct generic form.

1. ANTHRAPALÆMON GROSSARTI, spec. nov. Figs. 1–4.

A. biuncialis, cephalothorace quadrato simplici neque tuberculis nec spinis lateralibus ornato; rostro valido serrato, $\frac{1}{3}$ unciæ et ultra à margine projecto; sulco cervicali obscuro; carinâ posticâ brevissimâ incompletâ; abdomine (telsone lato trigono incluso) cephalothorace breviore.

Length, including the rostrum, 2 inches 1 line. Length of the squarish carapace, without the rostrum (which projects 5 lines in front), full $\frac{3}{4}$ of an inch. Width of the carapace, when crushed, exactly 1 inch; it was certainly not wider than long. It is only serrate near the front; and at the anterior angles a strong spine occurs. Body-rings 6 besides the telson, very short and very broad,—the length of the 6 rings being barely equal to the breadth of the abdomen, and even much less in the crushed fossil. The front ring, as usual, with abbreviated pleuræ; the second broadest (as in the Lobster); the 3rd, 4th, and 5th narrower and pointed; the fulcrum not very conspicuous; the articular area well marked out by a transverse ridge.

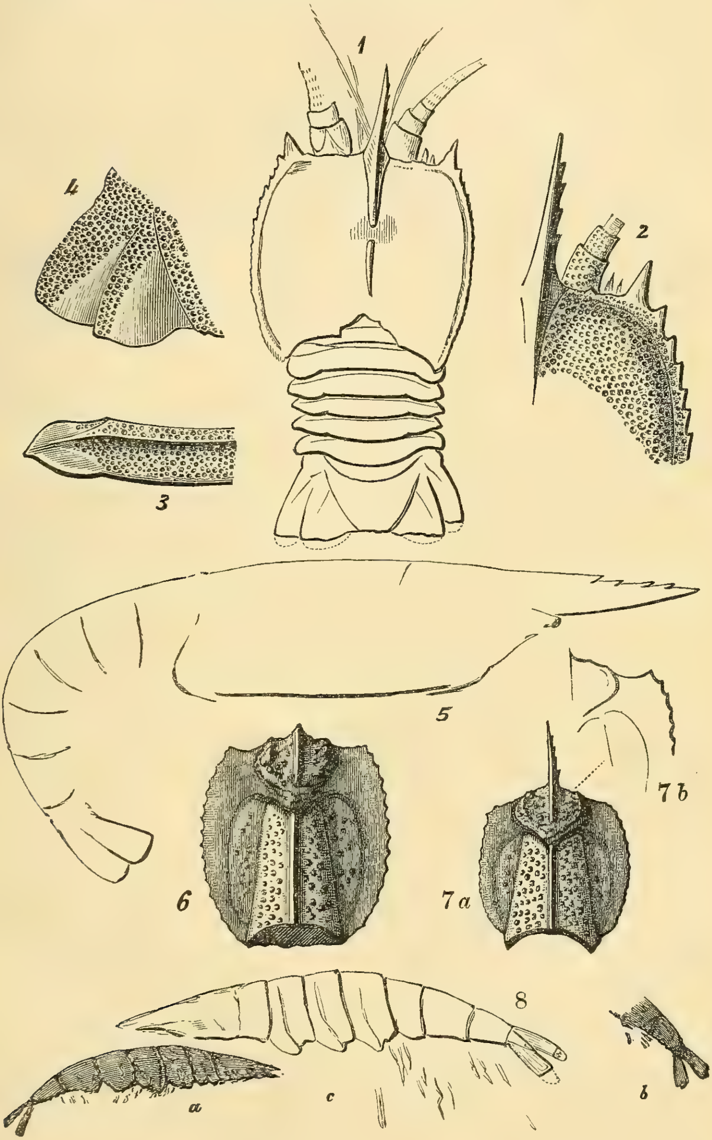
Telson almost an equilateral triangle, broader above than its length (the point is broken off, but was probably obtuse). Caudal appendages two on each side, with thickened outer margins, trigonal; the shape, however, is not complete: when spread out, as in the fossil, they extend beyond the width of the abdomen.

The entire surface of the carapace and body-rings is covered by minute depressions, like those on the posterior half of the Lobster's carapace. The serrations on the rostrum are minute; those towards the anterior angles of the carapace are also minute, except the large spines at the anterior angles.

Locality. Goodhock Hill, parish of Shotts, Lanarkshire: from the "slaty band" of the black-band-ironstone, associated with *Lingula, Conularia,* and Fish. Collection of W. Grossart, Esq.

2. ANTHRAPALÆMON. Sp., fig. 5.

Fig. 5 represents in outline a pencil-sketch supplied to me by Professor M'Coy, seven years back, when I first mentioned to him of the existence of this true Macrurous shield in the coal-measures. He told me then that he had no intention of publishing his sketches. I am not sure from what particular bed his fossil came, and shall be glad of information: it was from the Glasgow coal-field. From the rough sketch, it must belong to a much more elongate species than *A. Grossarti* ("5 inches long," according to M'Coy in his letter), Figs. 1—8. *Macrurous Crustaceans from the Coal-measures and Carboniferous Limestone.*



1. *Anthrapalæmon Grossarti*, sp. n. Nat. size. Lanarkshire. 2. Portion of the Carapace enlarged. 3. Part of a Body-segment enlarged. 4. Some of the Caudal Flaps enlarged. 5. Outline (from Prof. M'Coy's sketch) of a larger species of *Anthrapalæmon*. Lanarkshire. 6. *Anthrapalæmon* (*Palæocarabus*) *dubius*, Prestwich, sp. Nat. size. From Coalbrook-dale. 7 *a*. Another specimen, from Ridgeacre Colliery. 7 *b*. Portion of the Carapace enlarged.
8. *a, b, c. Palæocrangon? socialis*, Salter. From Fife.

probably even of a different genus; but in the absence of specimens it may be provisionally referred to *Anthrapalæmon* rather than to the next subgenus. The carapace in Prof. M'Coy's figure is smooth.

3. ANTHRAPALÆMON (*Palæocarabus*) DUBIUS, Prestwich, sp. Figs. 6 & 7.

Apus dubius, Prestwich (from Milne-Edwards's note) in Geol. Trans. 2nd ser. vol. v. pl. 41. fig. 9, 1840. *Macrura*, remains of, Salter in Morris's 'Catalogue,' 2nd edit. 1854. *Glyphæa? dubia*, Salter in Lyell's 'Manual,' 5th edit. p. 388, 1855.

A. (*P.*) biuncialis et ultra; cephalothorace oblongo-quadrato, tuberculis minoribus spinisque marginalibus ornato; rostro valido (serrato?) à carinâ posticâ longâ completâ omnino sejuncto; sulco cervicali conspicuo.

Length of carapace, without the mucro, 13 lines; width 12 lines. General form of the carapace (the only part known) rectangular-oblong, the sides somewhat arched outward; the front truncate, the hinder margin concave. The rostrum, projecting nearly $\frac{1}{2}$ an inch in front, is strong and prominent at its base, but runs a very short distance backward, and is then abruptly terminated by a wide concave space, $\frac{1}{4}$ of an inch broad, across which the cervical furrow, margined by large spinous tubercles, is faintly indicated.

The posterior keel commences abruptly, and is continued as an equal and rather strong ridge to the hinder margin; it is $\frac{1}{2}$ an inch long. The area on which it stands is flanked by two subparallel furrows (indicating, I suppose, the cardiac region); and the whole surface of the shield is rugose, as compared with that of *A. Grossarti*. Scattered spinous tubercles occur also over all the elevated portions. They are found, but of much smaller size, along the hollow space on each side, and are absent on the broad margin. They are largest around the rostral portion, two of them becoming spines in front. The serrations on the margin are strong and equal, about 14 on each side,—that at the outer angle not being stronger than the rest. The characters of the surface, therefore, distinguish the section from the type of the genus; and the two groups will, in all probability, be hereafter regarded as distinct.

To complete the account of the Macruran remains occurring in Upper Palæozoic rocks, it is necessary to refer to one or two other fragments. One which Professor M'Coy formerly thought to belong to the *Crustacea*, and figured under the name *Astacus Phillipsii* (Synopsis Carb. Foss. Ireland, pl. 23. fig. 1), was a very imperfect fragment, and has been since recognized by himself and others as merely an imitative portion of a brachiopod shell.

I am persuaded that I *have seen* a well-marked portion of a carapace in the true Mountain-limestone of Derbyshire. It was collected (among other treasures) by W. Hopkins, Esq., and still exists, I hope, in the Woodwardian Museum, though its small size may have caused it to be overlooked.

But if these be doubtful forms, there is one (fig. 8) which, now that the existence of true *Macrura*, with the ordinary number of segments, is known in the coal, can scarcely, I think, be referred to the *Amphipoda*: I refer to the *Uronectes* (*Gampsonyx*) *socialis*, *mihi*, published by the Rev. T. Brown in the Trans. Roy. Soc. Edinburgh, vol. xxii. p. 394.

The *Uronectes* (or *Gampsonyx*) of the Saarbruck coal-field (Palæontographica, vol. iv. p. 7, pl. 1) is described by Von Meyer as an Amphipod with characters of the Decapods, especially of the *Macrura* ("eine Amphipode mit Charakteren der Decapoden, insbesondere de Macrouren"). It has 14 free segments. But the species from the Scottish Carboniferous limestone (*U. socialis*), figured by me for Mr. Brown's paper, has much fewer (only 6 or 7) definite body-rings, like those of a Shrimp, with telson and caudal flaps, and, though indistinctly seen, probably a long carapace. It was an error hastily to compare it with *Uronectes*, and I will not commit another (until I see better specimens) by attempting fully to settle its position. Meantime, as I have since seen other specimens, I think it will be desirable to substitute the name *Palæocrangon*.

Palæocrangon, gen. nov.

Decapoda Macrura (*Palæmonidæ*?). A small Shrimp-like crustacean, with short, pointed carapace, and 6 or 7 body-rings, the front ones with expanded pleuræ. Telson small. Caudal appendages narrow, obovate. Feet —? Antennæ —?

1. *P. socialis*, Salter, Trans. R. S. Edin. xxii. p. 394. Carboniferous Limestone; Fifeshire. Fig. 8.
2. *P.* sp. Millstone-grit; Yorkshire, 1861. Undescribed.

These, it will be observed, are from the true Mountain-limestone series and Millstone-grit below the Coal.

No Decapod has been yet observed in the Lower Shales of the Carboniferous formation, where large *Phyllopoda* (and *Limulus*?) occur.

The Upper Devonian genus *Gitocrangon*, of Richter, figured by that author in his 'Beiträge Paläont. Thuringerwaldes,' pl. 2, seems quite undeterminable. It is, I should think, even doubtful, judging by the figures, if it be a Crustacean at all; but the description is by no means obscure, and the carapace, 7-ringed body, and tail-flaps could hardly have been mistaken by so good an observer.

June 19, 1861.

John Atkinson, Esq., Memb. Phil. Geol. Soc. Manchester, Thelwall near Warrington; Major Nathaniel Vicary, Westgate, Wexford; and Lord Rollo, 18 Upper Hyde Park Gardens, were elected Fellows.

The President made a communication on the part of the Council, that it is proposed to recommend to a General Meeting of the Fellows in November that the payments of future Resident and Non-resident Fellows be equalized.

It was proposed, seconded, and carried unanimously, that the Best Thanks of the Society be offered to the President for the labour and attention bestowed by him on the arrangement of the Foreign Collections in the Society's Museum.

The following communications were read:—

1. *On the* Lines *of* Deepest Water *around the* British Isles. By the Rev. R. Everest, F.G.S.

[*Abstract.*]

(The publication of this Paper is deferred.)

By drawing on a chart a line traversing the deepest soundings along the English Channel and the Eastern Coast of England and Scotland, continuing it along the 100-fathom-line on the Atlantic side of Scotland and Ireland, and connecting with it the line of deepest soundings along St. George's Channel, an unequal-sided hexagonal figure is described around the British Isles, and a pentagonal figure around Ireland. A hexagonal polygon may be similarly defined around the Isle of Arran. These lines were described in detail by the author, who pointed out that they limited areas similar to the polygonal form that stony or earthy bodies take in shrinking, either in the process of cooling or in drying. The relations of the 100-fathom-line to the promontories, the inlets, and general contour of the coast were dwelt upon; and the bearings that certain lines drawn across the British Isles from the projecting angles of the polygon appear to have on the strike and other conditions of the strata were described.

After some remarks on the probable effect that shrinkage of the earth's crust must have on the ejection of molten rock, the author observed that, in his opinion, the action of shrinking is the only one we know of that will afford any solution of the phenomena treated of in this paper, namely—long lines of depression accompanied by long lines of elevation, often, as in the case of the British Isles, Spain and Portugal, and elsewhere, belonging to parts of huge polygons broken up into small ones, as if the surface of the earth had once formed part of a basaltic causeway.

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2. *On the* Old Red Sandstone Rocks *of* Forfarshire. By James Powrie, Esq., F.G.S.

The stratified rocks of Forfarshire, to the south of the Grampian range, belong entirely to the Old Red Sandstone division of the geological series. They consist chiefly of coarse grits, dark-red and grey sandstones and flagstones, immense masses of conglomerate, with intercalated flagstones, sandstones, and shales, marly and argillaceous shales, and some crystalline limestones or cornstones. These, although in many instances broken up, and often faulted and contorted by trappean outbursts, all rest conformably the one upon the other. Thrown up against the flanks of the Grampian range at very high angles, and dipping towards the south-east, some very fine sections are afforded by the streams which, issuing from these mountains, cut through the sandstones, in many instances in a line almost at right angles to their strike. Of these the North Esk, the West Water, the Noran, and the Isla may be mentioned as affording peculiar facilities for studying these formations. In all places I have yet examined the Forfarshire sandstones are cut off from the schists and slaty beds of the Grampians by considerable outbursts of trap; it is, however, pretty evident that the sandstones overlie these schists unconformably. Although I do not intend at present to go at all into the geology of the Highland districts of Forfarshire, I may here state that it seems to me highly probable that these schistose beds may be the equivalents of some portion of the Lower Silurians. They apparently, for the most part, dip under the mountains in a north-easterly direction; but as this has in all probability been occasioned by these beds having not only been raised up, but actually tilted over, their true dip would seem to me to lie towards the south-west, while the overlying sandstones dip towards the south-east. In no instance have any organic remains been yet found in any of these more northern beds.

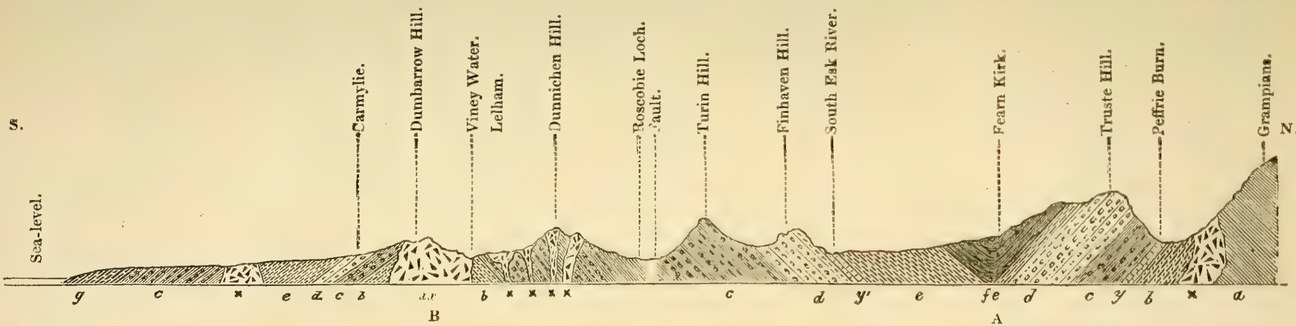
The geology of the Lowlands of Forfarshire is upon the whole exceedingly simple. It will be observed from the annexed section that a synclinal line occurs at no very great distance from the Grampians. This traverses the county in a line nearly parallel to these mountains. The section also shows an anticline existing about half-way between the syncline and the sea. This also runs nearly parallel to the Grampian range: entering Forfarshire from the German Ocean near to Montrose, it proceeds in an almost straight line through Rossie Moor, passes along near to the villages of Finhaven and Letham, crosses the south-east flank of the Sidlaws; thence it continues onwards a little to the south of Tealing and Baldovan House; west of Dundee Law, however, it bends off towards the north-west, and passes in that direction into Perthshire. Keeping these lines always in view, and also recollecting that several great faults occur immediately to the north of the anticline, all difficulties in the geology of the Forfarshire sandstones are readily surmounted.

It may be observed that the section here given is little else than a copy of that in Sir Charles Lyell's 'Manual of Geology*;' they only differ, I may say, in one particular, Sir Charles's section showing an overlying unconformable red sandstone, as found at Whiteness near Arbroath. On examining the rocks at this place, this is found to be undoubtedly the case. However, this overlying formation is not found on that part of the coast where my section terminates†. At Whiteness the rocks consist of a coarse red sandstone with many

* 4th edit. p. 48; and see also Sir R. Murchison's 'Siluria,' 2nd edit. p. 276.

† This paragraph has been re-written since the paper was read, and the opinion then stated (and published in the abstract of the paper), to the effect that the unconformity shown at Whiteness in Sir C. Lyell's section did not really exist, is now abandoned by the author.—Ed.

Section of the Old Red Sandstone Formation in Forfarshire, from the Grampians to the Firth of Tay. Distance about 22 miles.



A. Syncline.
B. Anticline.
x. Trappean outbursts. *x x x x.* This part very much broken up, the lower rocks repeatedly upheaved. *xx.* Great outburst, extending almost continuously from Broughty Ferry to Red Head, bringing the lower formations again to the surface. These traps for the most part consist of hard solid greenstones, occasionally, although but rarely, assuming the form of columnar basalt, as in the bed of the Isla below Reeky Linn, also felspathic and claystone porphyries and amygdaloids.
y. Concretionary limestone. *y'.* Lower bed. *y.* Upper bed.
a. Schists and slaty beds dipping under the Grampians.
b. Lower flaggy beds (tilestones?) with ripple-markings, impressions of rain-drops, &c., with dull-red sandstones and grits, their place along the Grampians often usurped by indurated or trappean conglomerates.
c. Conglomerates with intercalated red and grey sandstones, grey flagstones (Arbroath "pavement"), and shales, fossiliferous. Conglomerates towards the south of Forfarshire giving place to reddish sandstones.
d. Great conglomerate, but little developed south of B.
e. Thick-bedded red micaceous sandstones with Cephalaspid remains.
f. Dull-red thick-bedded sandstones, marls, and shales, with round greyish spots.
g. Red sandstones, red and yellowish marls, much mottled with round grey spots, supposed here to represent *d* and *e*.

Note.—At the time I wrote out the accompanying description of the Forfarshire rocks, I classed the spotted sandstones and marls lying betwixt the great outburst of trap (marked in the above section *x x*) and the sea as belonging to the upper portions of the Forfarshire sandstones. This I was induced to do, after very considerable hesitation, on account of these sandstones, &c., being very full of round greyish spots, similar in appearance to those found in the red sandstones of Clashbinnie and Fife, which are full of the scales and bones of *Holoptychius*, and thus undoubtedly the upper beds of these formations; but since sending off the paper, I have been able to procure from a bed of shale exposed on the banks of the Elliot, a small stream about 4 miles east from the line of the above section, *Parka decipiens*, with abundance of vegetable remains, quite similar to those found in the shales of the Turin Hill flagstones. These have only as yet been found in one stratum of this shale, but there in very great abundance, and from this I have also procured the head and a plate of, in so far as I can judge, a new species of *Eurypterus*. From this it would appear that the above-mentioned eruption had again upheaved the lower Forfarshire beds, and that the round grey spots are not confined to the upper beds.

The thickness of these formations may be roughly estimated as being not much under 3000 feet. Col. Imrie, in his section of these rocks as exposed in the bed of the North Esk, assigns 875 feet for the lower grits, and 1200 feet for the conglomerate. Between the syncline and the Grampians they generally dip at very high angles, the strata being in some instances almost perpendicular; betwixt the syncline and the sea, on both sides of the anticline, the dip seldom exceeds an angle of 22°.

imbedded pebbles, &c., evidently forming part of the upper portion of the great conglomerate of Forfarshire, and having a clearly defined dip of from 25° to 30° almost due south-east; but here, and also in a small bay a little to the north-east, there is an upper conglomerate overlying these sandstones in a nearly horizontal position. This conglomerate seems to be formed entirely of disintegrated portions of the lower rock, from which most of the finer particles have been washed away; it consists of water-worn pebbles in a siliceous matrix, with intercalated layers of coarse red and whitish sandstones, having all through, and especially in some of these intercalated layers, angular fragments of sandstones, occasionally of large size, with imbedded pebbles quite similar to portions of the lower rock. In the absence of fossils it may be quite impossible to fix the true age of this formation. Can it form part of the upper beds of the Old Red? This want of conformity has been observed in the Old Red Sandstone of other districts, and might fully account for the absence of any equivalents of the Caithness-shire fossiliferous beds. On the other hand, I have never observed any want of conformity betwixt the lower Forfarshire rocks and the upper Holoptychius beds, or betwixt these and the white Carboniferous sandstones of Fife; the junctions of these formations are, however, very obscure. My section is so far ideal, as I have introduced all the principal formations of Forfarshire, assigning to each, so far as in my power, its proper relative position; however, in no section of the county that I know are all these to be found. The great features are, however, pretty correctly taken from a line leading from the Grampians north of Fearn Church, at nearly right angles to the strike of these rocks, on to St. Andrew's Bay, a little to the east of the village of Carnoustie.

Commencing with the lowermost of the Forfarshire formations, we find a very considerable thickness of dark-red gritty beds, having very close to their base an intercalated bed of concretionary limestone or cornstone. Nowhere along the hills in Forfarshire is this bed exhibited; in Kincardineshire, however, it occupies a moderately prominent position, having been wrought to some extent at the Clattering Brig, at the south base of the Cairn o' Mount in the ravine a little to the east, called the Slack of the Birnie, and in other places. This same limestone has also been wrought where these formations have been again thrown up north of the anticline, at Millton of Mathers, and near the Dubton Station of the Scottish North-eastern Railway (both places in Kincardineshire), and at Buddonness, south of the anticline in Forfarshire. It is also found near Newburgh in Fifeshire, occupying the same relative position. Some distance above this limestone dark-red and rather indurated flagstones are also intercalated in these grits. These are well seen in a quarry on the north-west side of the road leading from the Clattering Brig towards Feltercairn, also in the bed of the West Water, underlying the conglomerates of Catterthun Hill; they are again thrown up and exposed at the fishing-village of Ferryden. Prof. Harkness suggested to me (and I think with much probability), that these might be the equivalents in time of, and here represent, the tilestones of the English formations. These grits pass upwards into conglomerates of very great thickness; in many localities their place is entirely usurped by the conglomerate. When this is the case, the conglomerate immediately succeeds the trappean outbursts, cutting off the sandstones from the schists; and here the matrix in which the pebbles are imbedded is almost always highly indurated, and possesses an almost trappean aspect. This matrix as it rises softens down until it becomes very similar in composition and hardness to the sandstones overlying and intercalated with the upper portions of this conglomerate. These conglomerates are thrown up in enormous masses along the flanks of the Grampians, forming a lower and interrupted range of hills, rising in several instances to heights of over 1000 feet above the sea-level. At some considerable elevation above the red-coloured flagstones or tilestones above mentioned, and near to where the indurated matrix softens down, are found intercalated (or rather, from their persistence, interstratified) flaggy beds, consisting of greyish thin-bedded and other sandstones, and greenish- and other coloured argillaceous shales. These, although by no means largely nor persistently developed to the north of the syncline, assume, when again elevated by the anticline, an importance beyond all the other deposits of Forfarshire; being not only largely wrought for economic purposes, but affording the only prolific fossiliferous beds of that county; I will therefore again revert to them. The upper portion of the conglomerate is very persistent in character along the Grampians, extending in a direction from nearly north-east to south-west almost from the German to the Atlantic Ocean. When the conglomerate is upheaved, however, by the anticlinal outbursts, this persistency ceases. To the north of this the conglomerate is still found in very large masses, as in the Garvock range of hills in Kincardineshire, and in the hills of Finhaven in Forfarshire. To the westward, as in the Sidlaw Hills, the conglomerate very much thins out; its place being almost altogether taken by sandstones, for the most part thickly bedded and varying in colour from bluish grey to greyish red. Still further to the west, however, we again find the same conglomerate very largely developed in Perthshire, as in the Ochil range to the north of the Bridge of Allan. Passing the anticline, the conglomerate is again seen in the section afforded by the coast betwixt Montrose and Arbroath, where it forms the bold promontory called the Red Head, from whence it extends on to beyond the fishing-village of Auchmithie. All along this line the action of the waves has cut it out into most picturesque gullies, ravines, and caverns. In the inland parts of Forfarshire, to the south of the anticline, it is only found intercalated, in not very considerable quantities, with the red and grey sandstones, which here seem in great measure to have usurped its place. In the upper portions of the conglomerate, intercalated beds of coarse red sandstones become more and more abundant, until at last this formation passes entirely into thick-bedded sandstones, generally highly micaceous, and affording an excellent and durable building-stone of a rather pleasing red colour. Nearly where the conglomerate passes into this sandstone is found in some places north of the anticline an intercalated bed of concretionary limestone, very similar in character to the already-mentioned lower bed. This has been wrought, although to no great extent, in several places, as at Trinity Muir, near Brechin, Strickathrow Hill, and in Kincardineshire in the Garvock range. A sandstone of a dull deep-red colour, soft, and weathering fast on exposure to atmospheric influences, is generally found overlying the above-mentioned micaceous sandstone; this being again overlain by deep-red and also sometimes by whitish and greyish marls and shales, forming the uppermost of our Forfarshire Old Red Sandstones. These are remarkable, and may be pretty readily distinguished by being very full of peculiar greyish-coloured round spots, varying in size from about one-tenth of an inch to over one inch in diameter. In many instances these are so numerous as to give the sandstones quite a mottled appearance. These overlying sandstones are, however, by no means very persistent either in character or appearance; in some instances one or other being absent, while in many cases they seem to pass into one another.

Until comparatively a recent period the Forfarshire rocks were considered as particularly destitute of fossils, and even yet the known fossiliferous deposits are principally, if not altogether, confined to the flagstones and shales intercalated in the conglomerate. In no instance have any of the limestones as yet yielded any trace of organic remains; and equally destitute of these have all the upper marls and shales as yet proved. In giving a very short notice of such of those deposits as have shown any vestiges of the plants or animals existing in times of such remote antiquity, it may be well to take them in the order of their superposition. Lowermost we have the dark-red, rather indurated flagstones; and even in these as yet no recognizable remains, either animal or vegetable, have been found. Their beautifully perfect ripple-markings, however, prove that they had been deposited in a shallow sea over which the winds blew and the waves rolled; and being in some instances completely covered with trails of Crustaceans and Annelides, the existence of such cannot be doubted, while deeply pitted indentations, as of rain-drops, show that the sands and muddy banks of these shores, when uncovered by the tide, were not without rain. The Rev. Hugh Mitchell, whose labours have added so much to our knowledge of the Forfarshire organic remains*, has in his collection several beautifully characteristic slabs of these flagstones, dug by him at Ferryden, where they have been upheaved. Considerably above these and intercalated in the conglomerates are found the beds already mentioned, from which the well-known Arbroath "pavement" has been so largely dug. These are highly interesting to the geologist, as affording samples of all the organic remains that have yet been found in Forfarshire; indeed, with the exception of *Cephalaspis*, which has been recovered from sandstones considerably overlying them, none other of the Forfarshire

* See above, p. 145, &c.

rocks have yet yielded any organism, whether animal or vegetable. These beds consist of thin-bedded grey flagstones, red and grey sandstones of some thickness, and greenish and bluish argillaceous shales. In these by far the most abundant organism is the *Parca decipiens*; next plentiful are the remains, commonly broken, of segments of the great Forfarshire crustacean, the *Pterygotus Anglicus*. These as well as the *Parca* are found more or less well preserved in both shales and sandstones; with these are associated the remains of other *Crustacea*, as the *Stylonurus* of Mr. D. Page. Annelid-tracks and burrows are also occasionally to be met with in the sandstones. After these, but much more rare, are found portions of the head-plate of *Cephalaspis*; anything approaching to complete specimens of this fish being very seldom found in any of the many localities where these flagstones are largely wrought. A peculiarity regarding the remains of *Cephalaspis* is, that they are always found in the sandstones; I have never yet seen the smallest vestige of them in any of the shales, although full of other remains: occasionally a fish-spine may also be picked up. The Farnell Beds, which have yielded so many interesting vestiges of the very remote period when these flagstones and shales were deposited, belong to this same portion of the Forfarshire sandstones. They were noticed several years ago by the Rev. Mr. Brewster, of Farnell, as likely to prove fossiliferous. It is to the Rev. Mr. Mitchell, of Craig, that we are indebted for first discovering the nature of these fossils; his indefatigable researches were rewarded by the discovery of two small Ganoid fishes, named by Sir Philip Egerton *Acanthodes Mitchelli* and *Climatius scutiger*; also several varieties of *Crustacea*. The liberality of the Earl of Southesk has since largely opened up this deposit, and allowed its treasures to be examined and preserved to a great extent by Mr. Brewster and myself. My only regret is that, from the dip of strata making the working now not only expensive but difficult, and no product of economic value being obtained from it, it must be looked on as all but exhausted. We have, however, already been able to add to the above-named fishes several others, mostly as yet unnamed; amongst these is a *Diplocanthus*, named by Sir Philip Egerton *D. gracilis*; also a goodly sized Placoid, at present being described by this distinguished ichthyologist. Several remains of *Pterygoti* and other *Crustacea* have also been found; some of them apparently new. Mr. Walter McNicol at Tealing has since discovered several localities, mostly in the Sidlaws, where the same fishes are to be found, although not so perfectly preserved. It is worthy of remark that the common colour of the shales, which alone are fitted for preserving such organisms, belonging to these flagstones, is of a light greenish hue; in these no vestige of ichthyic remains has yet been found. The colour of the shales where Mr. McNicol has found these fishes, &c., is light blue; while the Farnell shales vary from a fine cream-colour to a dark grey. The vegetable remains of these beds are generally very imperfect and unreadable. The only instance in which a plant clearly belonging to the land has been disinterred occurred about twenty years ago, when what was called by the quarrymen a small tree was dug out, and by them cast aside as useless. On hearing of this discovery, unfortunately not until months elapsed, I could recover only a small portion of the root, seemingly of some Lepidodendroid. This was noticed and described, from data furnished by me, by the late Hugh Miller at the Meeting of the British Association held at Glasgow in Sept. 1855 (see his 'Testimony of the Rocks,' p. 447). Generally these vegetable remains appear to have formed parts of marine or at least aquatic plants. None of the other sandstones intercalated in the conglomerate have yet proved fossiliferous. The micaceous solid-bedded sandstone, however, into which it has been stated the conglomerate passes, has yielded some of our finest specimens of *Cephalaspis* (no crustacean remains are found in our rocks overlying the flagstones). The rock near Bridge-of-Allan, whence I procured the two specimens of *Pteraspis* now in Professor Huxley's hands, occupies identically the same position as this sandstone, and although lighter coloured, its lithological character in other respects is quite similar; and although no specimens of this fish have yet been saved from the rocks in Forfarshire (these specimens being the only ones yet recognized in Scotland), yet I have little doubt that it is not altogether wanting there. Indeed I suspect that some specimens from this same sandstone, which, I must confess, I years ago cast aside as mere worthless fragments of *Cephalaspis*, were in reality portions of the head-plates of *Pteraspis*.

From none of the other and upper beds of Forfarshire have any fossils of any kind ever yet been obtained; their quality rendering them unfit for building, and generally being covered by the rich clays of the Valley of Strathmore and its continuation, the opportunities for studying their nature are not so frequent. Whether they are the equivalents of the red Holoptychian beds of the Carse of Gowrie (Clashbinnie, &c.) is yet to be determined. One thing is deserving notice—namely, that they are, equally with the Carse of Gowrie, red sandstones much mottled with circular spots of a greyish colour. Although I have examined hundreds of these spots in the Forfarshire sandstones, in no instance, however, have I detected anything organic in them; while Dr. Anderson, of Newburgh, states* "that portions of scales and minute bones have been detected in the centre of the spots" from sandstones belonging to the Carse of Gowrie.

It is now allowed that the lowermost of our Forfarshire sandstones belong to the lowest of the Old Red formations, thus underlying the Caithness beds, &c.; their peculiar *Crustacea* as well as the Cephalaspid remains evidently closely uniting them to the Upper Silurians; while at the same time the Ganoid fishes, belonging in some cases to the same genera, and in other respects much resembling those of the more northern rocks, indicate also a near alliance with these formations. Again, our upper beds, if not identical with, evidently as nearly approximate to, the Holoptychian sandstones of Clashbinnie, &c. No want of conformity in our Forfarshire rocks shows any break in the continuity of these deposits; yet nowhere have I detected what could be considered the equivalents of the Caithness beds. Does this in-

* 'Dura Den,' p. 26.

dicate the probability of an immensely lengthened period during which there was gradual sinking, followed by as gradual an uprising of the sea-bottom, unaccompanied by any of those violent volcanic eruptions so common during the Carboniferous era? Several reasons, in my opinion, concur in rendering this by no means improbable. That these deposits were accumulated during a period of comparative quiescence is shown by the entire absence of intercalated traps or other igneous rocks. The Forfarshire sandstones are very frequently found disrupted, they are often overlain by large flows of igneous matter, intruded traps are found all over the county; but in no place have I ever yet seen these traps again overlain by the sandstones, thus evidently proving the trap-rocks to belong to a later geological epoch. A gradual submergence is, I think, equally clearly indicated during the period while the lowermost rocks were being laid down; the very undermost of our fossiliferous beds with their beautifully preserved ripple-markings, Crustacean trails, and even rain-prints, evidently point to a sea-beach left frequently dry by the ebbing tides. Above these the shales, mixed up with the sandstones full of Vegetable and Crustacean remains, still indicate ebb-waters; but now the ripple-markings, although yet to be seen, are much less distinct, Crustacean or other tracks become exceedingly rare, and rain-imprints cease to be recognized; the *Cephalaspis*, a fish evidently having a wide range in time and space, is found, all showing a sinking of the sea-bottom. Still rising in the series, we find that the sea has further deepened; the conglomerates, only formed near a shore, cease, and sandstones, having no organic remains except an occasional *Cephalaspis* or *Pteraspis*, take their place; still the sea deepens and the land recedes until almost no deposit, and what there is barren of organic remains, takes place. A long period intervenes during which the Caithness beds form the bottom of shallower, or at least much more life-sustaining waters. At last this depression comes to a close, and as gradual an upward movement takes place; and again sediments are accumulated, now entombing a new class of animals, the *Holoptychius* and his allies taking the place of *Cephalaspis* and the *Crustacea* of the more ancient ocean. This upheaval continues, violent volcanic commotions take place, and Forfarshire from being a sea-bottom becomes high land, while in the lower districts the coal-measures are being accumulated.

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3. *On the* LUDLOW BONE-BED *and its* CRUSTACEAN REMAINS.
By J. HARLEY, M.B. Lond.
[Communicated by Prof. HUXLEY, Sec. G.S., &c.]

[PLATE XVII.]

IT is well-known to geologists, that between those two great systems of rocks the Silurian and Old Red Sandstone, there occurs an intermediate series of relatively small development, which, as it partakes of the lithological and palæontological characters of both systems, has been well called "Transition-beds."

Transition-beds with contained Bone-beds.—That part of these beds which immediately overlies the Upper Ludlow Rock is composed of soft argillaceous shales; and that which immediately underlies the Old Red, of a soft, yellow, fine-grained sandstone—the Downton Sandstone.

Just below the Downton Sandstone, and therefore in the lowest part of these transition-strata, appears that remarkable animal-deposit called the "Ludlow Bone-bed"; and just above the Downton Sandstone, standing indeed within the threshold of the Old Red, another animal-deposit occurs, rarely, however, as an isolated conglomeration of organic remains as in the bone-bed, but most commonly having these more or less freely diffused throughout argillaceous and arenaceous strata, or a gritty calcareous conglomerate which often becomes a compact bluish limestone. Thus, to speak generally, we have a lower bone-bed more appertaining to the Silurian system than to the Old Red; and an upper, more diffuse one, much more closely associated with the Old Red than with the Silurian Rocks. Both have their types at Ludlow,—the former in Ludford Lane and the north-eastern slopes of Whitcliffe; the latter in the strata exposed on the south bank of the Teme, opposite to the Gas-works and Paper-mill.

Ludlow Bone-bed.—It is to the older and lower, or Bone-bed proper, that I would draw attention, premising a few general remarks. The Ludlow Bone-bed was at first considered to be a local deposit; but later researches have shown that it extends interruptedly over an area of forty or fifty miles*, a fact which renders probable that it will be found to have a still more general distribution. As it occurs at Ludlow and in its neighbourhood it forms a thin seam, varying in thickness from half a foot to the eighth of an inch, or rather to nothing; for it gradually thins away, and here and there disappears altogether, and we consequently fail to trace it for a distance. Interruptions which thus occur locally and on a small scale may probably occur on a large one throughout these early rocks, and so account for the absence of the bone-bed in wide geological areas. Whenever it does occur, it becomes an infallible guide to the geologist.

Sir R. Murchison has described the bone-bed as being composed of "a matted mass of bony fragments, some of which are of a mahogany hue, but others of so brilliant a black, that, when first discovered, they conveyed the impression that the bed was a heap of broken beetles" ('Siluria,' second edit. p. 148). The bed is often very compact and of a lighter colour, and closely resembles the cake from which linseed-oil has been expressed.

All that we know of the constituents of this remarkable deposit is contained in about two pages of the text and an illustrative plate of the 'Silurian System.' There we learn that, with the addition of a few molluscan shells†, it is composed of the remains of *Sclerodus*, *Plec-*

* 'Siluria,' and Quart. Journ. Geol. Soc. vol. ix. p. 11.

† The remains of Molluscs occurring in this bone-bed belong to *Discina*

trodus, and *Thelodus*, which are stated to be fishes*. Length of time has rendered us familiar with these names, but has failed, except perhaps with regard to one of them, to extend our very imperfect knowledge of the animals which they serve to designate. And this is not to be wondered at; for the remains are so very fragmentary, brittle, and coherent, that the utmost patience and no little labour are required to enable one to succeed in obtaining any definite results. Difficulties, however, do but enhance the interest which naturally attaches itself to this deposit; for, whenever and wherever animal life may have been first endowed with forms which characterize that highest type of it called vertebrate, it is in this bone-bed that we find the first assurances of the varied existence of this type. I say "varied;" for the Ludlow rocks have furnished a single species of *Pteraspis*, which seems to have appeared in almost solitary dignity to proclaim the dawn of a higher existence to a world of Crustaceans and Molluscs. To ascertain in what forms this higher existence, as we find it in the bone-bed, begun—whether it was some creation distinct from both that which preceded and that which succeeded it, or whether it is one of the necessary connecting links in a progressive development of life which runs uninterruptedly throughout the older rocks, are the inducements to the careful study of this complex mass. In examining this deposit, however, there are other and more preliminary questions which require to be answered first; and it is the solution of one of these which is the chief object of this paper.

Crustacean life in the Silurian age.—The Silurian was essentially a Crustacean age, and one that maintained its full vigour throughout the transition-strata to which I have referred. My first endeavour, therefore, was to ascertain whether the bone-bed contains Crustacean remains. I find that it does, and in no inconsiderable quantity; and I now proceed to lay the evidences before you.

Crustacean remains in the Ludlow Bone-bed.—On making diligent examination of the broken and washed deposit, with the aid of a pocket-lens, I find a number of minute bodies of various but often related forms, which, for convenience of general description, I will divide into three classes.

1. Of the bodies which I have placed in the first class, some resemble the minute conical teeth of osseous fishes, others appear to be made up of two, or occasionally of three such teeth (figs. 1–4). Rarely, one meets with what at first sight appears to be a very minute jaw set with a row of conical teeth (fig. 15), and more rarely still, with microscopic curved fangs or spines (fig. 16).

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rugosa, *Lingula cornea*, *Orthis lunata*, *Rhynchonella navicula*, and some indeterminable genera.

* I have submitted all the remains which are thus designated to careful microscopical examination, and find that they possess a true bony or dentinal structure. While I thus disprove Prof. McCoy's supposition that *Plectrodus* and *Sclerodus* are Crustacean fragments (Quart. Journ. Geol. Soc. vol. ix. p. 14), I agree with him that the parts figured in the 'Silurian System' under these names cannot be teeth or jaws; they are, I believe, the posterior spines of the cephalic plate of some Cephalaspidean fish.

These last two varieties are very interesting as being in external form, and, as I will show, in all other respects, identical with Pander's "Conodonts."

In an elaborate monograph on the fossil fish of the Silurian system of the northern part of Russia, Dr. Pander has described a host of tooth-like bodies which he has assumed to be the teeth of Fishes, and to which collectively he has given the term "Conodonts," and subdivided them into 13 genera, comprising 56 species. They are of two kinds, simple and compound. The simple resemble minute spines about a line in length; under a magnifying power many of them look like the stout curved thorns of a rose-stem; they are plane, or furrowed longitudinally, more or less compressed and hollow at the base, which is expanded with an everted margin. The compound ones are larger, and resemble small jaws, each beset with a row of conical teeth, which may be equal or unequal, the row being often terminated and sometimes interrupted by larger fang-like elevations. These Conodonts were at first stated to be composed of pure carbonate of lime; but on re-examination, they were found to contain phosphate of lime also, which strengthened Dr. Pander in his supposition that they were fish-remains. As described by him, they are white and opake, with transparent edges,—or reddish-yellow, transparent and horny looking, and under a high magnifying power show nothing but homogeneous superimposed layers.

2. To return to my own forms. The second class of bodies may be likened to the crown of a bicuspid or molar tooth, and especially as we should find them beneath the gums of a new-born child (figs. 5, 6, 9). The upper surface presents three more or less elevated and rounded cusps; the lower surface is excavated into depressions corresponding to the cusps. This form, on the one hand, by losing elevation, becomes a mere tuberculated plate or scale; and on the other, by lateral extension of the ridges joining the cusps, the little bodies present a V-shaped elevation (fig. 11). By the combination of two such, we have an undulated plate surmounted by a W-shaped elevation (fig. 12).

The bodies included in the first and second classes are very hard, have a rich brownish-red or amber colour, and are semitransparent, and highly polished. When possessed of but little colour, they appear to be composed of discoloured ivory, and occasionally present longitudinal converging striæ, due to coloured lines traversing the semitransparent substance; sometimes it is difficult to say that these are not linear elevations.

From their external form and ivory-like consistence and appearance, I was at first induced to think that some of these tooth-like bodies were teeth, probably of Fishes; but the variations presented by others, and their declination into mere tuberculated plates, ultimately persuaded me that this could scarcely be a correct supposition.

3. In the third class we find small thick plates of a somewhat oblong form, not exceeding two lines in length, and about a fourth of a line in thickness. There are three pretty distinct varieties. The first is distinguished by having one of its surfaces raised into three nearly

equal rounded tubercles, bounded (at least in one direction) by the slightly elevated margin of the plate (fig. 18). The second is somewhat pyriform in outline, and presents usually one small tubercle at the narrow end; sometimes there are two, and occasionally three, more or less separate and distinct (figs. 19, 20). The third variety occurs as oblong or rounded plates either plane or with one surface slightly concave and the other slightly convex.

The bodies placed in this class are commonly of a greyish or blackish-brown colour; and a fractured edge presents an excessively fine fibrous structure.

All the forms included in the above three classes, and all their varieties, possess the same ultimate microscopical structure and chemical composition.

Structure.—The structure, which is perfectly preserved, is unmistakeably Crustacean. A microscopic section presents a vertical tubular, and a horizontal laminated structure. In the flattened bodies these two structures are strictly perpendicular to each other; but in the conical bodies, except about the apices, they have a more or less oblique relation (figs. 12 *b*, 12 *c*).

The tubes are excessively fine, varying from about the $\frac{1}{40000}$ to the $\frac{1}{25000}$th of an inch in diameter. In most specimens they appear to be injected with a reddish-brown material; but this rather stains the walls of the tubes than fills up their cavities; for in transverse section they appear as clear dots with a discoloured circumference, and on placing the bodies in hot turpentine, minute air-bubbles are freely displaced. The above is therefore probably an overstatement of their real size. The tubes are so crowded, that there appears, in vertical sections, to be little or no intertubular substance; they lie parallel to each other, and never branch; and when the surfaces between which they pass are parallel, they take a straight course; but whenever an elevation occurs, the tubes, instead of converging towards the apex, take a slight bend outwards to either side of it. Minute, rounded or oval, calcareous corpuscles, measuring about the $\frac{1}{3000}$th of an inch in diameter, are often present. In horizontal sections, the tubes appear to be arranged in systems forming rounded sinuosities separated from each other by clear tortuous lines of intertubular substance (fig. 20 *a*).

The horizontal lamination presents the appearance of a great number of excessively fine, and usually faintly marked, wavy lines, the undulations of which are very minute, regular, and parallel to each other (fig. 12 *d*). The Conodonts possess the same structure. The form called *Gnathodus Mosquensis*, tab. 2 *a*, fig. 10 in Pander's work, of which I have found several specimens in the bone-bed (one is delineated in fig. 15), shows both the laminated and tubular structure; the tubes, however, are rarely stained or injected.

In the fang-like form, of which, strange to say, I have only found a single specimen (fig. 16), and which corresponds to the genus *Acodus* of Pander, the same structure is recognizable. But the tubuli are rarely injected; and, since in these forms they have a direction almost parallel to the laminæ, it is difficult, if not impossible, to distinguish between them. The injection, however, of a few tubuli here and there manifests their presence and direction.

General remarks on arrangement of tubuli in Crustacean shell.—This alteration of the relative directions of the laminæ and tubuli is what occurs in the other forms of Crustacean fragments to which I have referred; and I also find a corresponding obliquity of their arrangement in the spines of recent *Limuli.* The same rule, in fact, applies to both the recent and fossil integument; viz., whenever the surface is elevated into a tubercle, the tubes have a direction a little oblique to its surface; on the sides of a conical eminence the tubuli lie at an acute angle; and when the eminence is included between lines that are parallel, or nearly so, then the tubuli, as in the spine-like Conodonts, take a direction almost parallel to the surface. Calcareous corpuscles also occur in the Conodonts, and are, I presume, the "nuclei or cells," which have been mentioned in the description of these bodies. I am much indebted to Professor Huxley for two specimens of Conodonts received from Dr. Pander. They have proved a most valuable donation, since they have enabled me to investigate their structure and determine their identity with my own solitary specimen.

Chemical constitution.—Chemical analyses of each of these three classes of bodies prove that they have the same composition; and as far as the eye can judge of the results of operations on small quantities, the proportion of their constituents appears to be equal in all. They are composed of phosphate and carbonate of lime, the former being, contrary to my anticipations, the more abundant constituent. The colour is due to sesquioxide of iron.

Relationship.—Having thus determined that the bodies above referred to, including the Conodonts of Pander, are Crustacean fragments, it remains to determine, as far as possible, to what particular genus or genera they belong.

So great is the number, and so varied the forms of the parts of a Crustacean, that it would be quite allowable to suppose that all the forms figured in the first four plates of Dr. Pander's work (which include representations of all the thirteen genera into which he has subdivided the Conodonts) may belong to a single individual; and the same may be said of all the forms which I have figured; but perhaps it would be nearer the truth to assume that they have a more distant relationship than this. May they not belong to several or all of the orders and genera common to the strata in which they lie?

Structure of Pterygotus.—The question may be restricted somewhat by ascertaining the structure of some of these. First, with regard to that widely diffused genus *Pterygotus.* I infer that its integument was very soft, and almost wholly composed of animal matter, from the fact that it invariably occurs as a carbonaceous film. We find the bony plates of *Pteraspis* and the testa of Trilobites and Phyllopods well preserved in the mudstone-shale of the Lower Ludlow strata; but even in the calcareous seams of the Upper

Ludlow, *Pterygotus* still remains as a flimsy trace, or dark stain*. I am not justified, therefore, in referring any of these fragments to this genus or its allies, unless, indeed, they have such forms as are represented in figs. 11, 12, and 13, which may possibly be stomach-teeth.

Structure of Trilobites.—As to the Trilobites, they have a structure altogether different from that above described. I have examined the integument of *Calymene Blumenbachii*, *Harpes macrocephalus*, and *Phacops latifrons*: Mr. Salter kindly furnished me with material for examining the last two genera. They all agree in structure; and as this is best seen in the dark-coloured *Calymene* from the Lower Ludlow strata, I will take this as the type. The integument of this genus is seen in vertical section to consist of two distinct portions, an inner and an outer; and both are traversed by wide straight tubes, from $\frac{1}{5000}$th to $\frac{1}{1400}$th of an inch in diameter, placed at a distance of about $\frac{1}{500}$th of an inch apart, so as to be quite isolated from each other. The outer part of the integument has a coarsely fibrous appearance, the fibres having a horizontal direction, and uniting obliquely to form a coarse network with narrow elliptical meshes. I question whether this is a true structural appearance. Magnified 300 times, this part of the integument presents obscure indications of a finely laminated structure. In specimens from the limestone the inner part of the integument has a prismatic structure; but I believe that this is due to crystallization of the infiltrated carbonate of lime; for I do not observe it in specimens from the mudstone. Moreover, the Trilobites do not appear to have possessed articulated appendages.

Structure of Ceratiocaris.—On the other hand, the structure of the bodies in question has a great resemblance to, if not a complete identity with, that of *Ceratiocaris*. In a section of one of the tail-spines of this genus from the Upper Ludlow rock, I find both the tubular and laminar systems well displayed; but the laminæ, instead of being faintly marked, are clearly and sharply defined, and the tubuli are perhaps less crowded, and sometimes beautifully zigzaged near their termination at the outer surface. There is another and more general agreement between the bodies compared. The Phyllopods of the Ludlow rocks are small, many being not much larger than big prawns; and they possessed a very hard integument, as is proved by their remains. Further, these little animals were very spiny, for even the tail-spines themselves were armed with minute secondary spines disposed in longitudinal rows.

Discrimination.—Now, while their microscopic size and extreme hardness separate the little bodies referred to in this paper from *Pterygotus* and its allies, and their structure from the Trilobites, these characters all serve to associate them with the Phyllopods.

* In the large Lesmahago specimens, in which the integument is best developed and preserved, it appears in vertical section as a black line, the $\frac{1}{300}$th of an inch only in thickness, and no structure can be made out either in this or in a horizontal section.

Indeed, I am almost convinced that many of the simple Conodonts are really the minute spines which were attached to the tail-spines of *Ceratiocaris*. Some of these are repeatedly grooved in the longitudinal direction; so are many of the Conodonts. Some tail-spines in my possession possess rows of little oval apertures which correspond to the attachment of the secondary spines, which were no doubt moveable; and these apertures correspond in size to the bases of the Conodonts. Further, the Conodonts are most abundant in those strata where, in this country at least, the Phyllopods are most common, viz. in the Lower Ludlow.

While I would thus dispose of the spine- and tooth-like bodies, I am much puzzled about a reference for the plates or scales. They look at first sight like fragments of Trilobites; but, apart from their difference of structure, the irregularity of their tuberculation and their isolated entirety separate them from these animals. Are they the disunited and symmetrical pieces of such a tessellated carapace as is found in the recent genus *Birgus*? (figs. 18, 19).

Both the Conodonts of Pander, and the fragments which I have described in this paper, have resemblances to the recent genera *Squilla* and *Limulus*. In structure they exactly agree with the latter, the carapace of which shows no differentiation into outer and inner portions; and the whole thickness is traversed by simple, uniform and straight, or slightly bending tubes.

Bodies similar in form to many of those figured in tab. 1 and 2 of Dr. Pander's work are to be found articulated with the margins of the carapace of *Limulus*, and fringing the caudal appendages of some species of *Squilla*. Indeed figs. 22 and 23, tab. 2, are exact representations of the posterior margin of the caudal segment of a species of *Squilla* in the Museum of Comparative Anatomy at King's College.

Astacoderma.—In order to facilitate the recognition of the bodies mentioned in this paper, I propose to form them into one provisional genus, from which, as each is more particularly identified, it may be withdrawn. *Astacoderma* is the name I would give this genus, in which I would also include the whole of the so-called Conodonts, and thus give them at once a natural association, and a more appropriate name.

I will now briefly describe such of the more typical forms as often occur in the Bone-bed.

ASTACODERMA TERMINALE. Pl. XVII. figs. 1 & 14.

About a line in length, conical, round or compressed and subangular, hollow, the cavity usually extending about two-thirds the length. Fig. 14 is an irregular form.

A. BICUSPIDATUM. Pl. XVII. figs. 2, 3, 4, 7.

Rarely exceeding a line in length, and about as broad; cusps usually equal, vertical or oblique, each hollowed at the base into a little conical cavity. In fig. 7 the cusps are confluent.

These two species were probably the hard extremities of limbs.

Loc. Ludlow and Norton.

A. SERRATUM. Pl. XVII. fig. 15.

Very minute (fig. 15 does not exceed a line in its greatest dimension); the cusps are sometimes unequal and irregularly arranged; dark streaks indicate cavities at the bases of the cusps.

This is the *Gnathodus* of Pander. It is doubtless the serrated margin of some carapace or body-ring.

Loc. Ludlow.

A. SPINOSUM. Pl. XVII. figs. 16 *a*, 16 *b*.

The simple Conodont of Pander, corresponding to the genus *Acodus*. Spines of *Ceratiocaris*, or of some Squilloid Crustacean.

Loc. A solitary specimen in the Bone-bed, Ludlow.

A. TRIANGULARE. Pl. XVII. figs. 5 *a* & 5 *b*.

Triangular, subpyramidal, broader than long, terminated by three cusps, two anterior, the third posterior and intermediate, more prominent than the anterior; inferior surface (5 *b*) presents three depressions in a general concavity, corresponding to the cusps.

Var. *diffusum* (fig. 6).

Var. *contractum* (fig. 8).

Loc. Ludlow and Norton (common).

A. DECLINATUM. Pl. XVII. fig. 9.

Odd cusp anterior, depressed, forming the termination of a ridge running downwards and forwards from the left posterior cusp; between this ridge and the right posterior cusp is a deep depression which slopes downwards to the right side. Inferior surface concave, presenting a general concavity with three depressions corresponding to cusps.

Var. *depressum*.

Var. *expansum*. Anterior cusp carried towards the right side, so as to be nearly in front of the right posterior; depression almost transverse, wedge-shaped.

Var. *expanso-acuminatum* (fig. 10). This variety serves to connect, through fig. 8 (*A. triangulare*, var. *contractum*), the last two species described. I am at a loss where to affix these bodies; but the varieties delineated in figs. 8 & 10 are identical in form with some of the stunted spines articulated to the margins of the abdominal plate of *Limulus*.

Loc. Ludlow and Norton (frequent).

A. UNDULATUM. Pl. XVII. figs. 11, 12*a*—12*d*, 13.

Cusps obsolete or nearly so; the two intervening and diverging ridges forming a V-shaped elevation, from which the rest of the surface declinesion. This is only a declens of variety *expansum*.

Var. *compositum*. A combination of two or even three such forms, making a zigzag plate, bounded by a smooth, slightly elevated margin. The under surface presents usually, but not invariably, depressions corresponding to the elevations. This form is not unlike the stomach-teeth of the common Lobster.

Loc. Ludlow and Norton (not very common).

A. PLANUM. Pl. XVII. figs. 18, 19, 20*a*, 20*b*, 20*c*.

Flat smooth plates, with rounded polished, or straight (sometimes polished, sometimes unpolished) edges, often as much as $\frac{1}{4}$ of a line in thickness. Superior surface slightly concave, or distinctly included within a raised margin, occasionally marked just within the margin with minute pits or radiated linear depressions; inferior surface also slightly concave, and partially bounded by a smooth elevated border.

Var. *monotuberculatum* (fig. 20). Sometimes the linear depression here shown, but which is not present in the typical form, becomes very wide; and then the one-half of the plate is occupied by two tubercles (fig. 19).

Var. *trituberculatum* (fig. 18). Oblong or pyriform; the superior surface presents three pretty equal rounded tubercles, bounded in one direction by the elevated margin of the plate. These forms resemble the valves of some species of *Beyrichia*; and had they possessed a more delicate structure and a greater concavity of one surface, one would have been induced to refer them to these Entomostracans.

Loc. Ludlow and Norton.

This form and its varieties are very common, and make up a considerable proportion of the "black scales," of which the bone-bed appears to be in great part composed. They may possibly belong to some Limuloid Crustacean.

A. REMIFORME. Pl. XVII. fig. 17.

Flat, triangular; superior surface convex; inferior a little concave. The superior surface presents near the base a transverse depression, alternately convex and concave, apparently for ginglymoid articulation.

I have met with this form twice only. It resembles some of the little paddle-like appendages to the posterior limbs of *Limulus*.

Loc. Ludlow and Norton.

Dr. Volborth's discovery of Conodonts in the Ludlow Bone-bed.—I would mention in conclusion, that I had, last summer, the pleasure of showing my specimens of Conodonts from the Bone-bed to Dr. Volborth of St. Petersburg, a very eminent authority in this matter, and that he unhesitatingly confirmed the view I had taken of these bodies, as to their being identical with Dr. Pander's Conodonts.

On the 30th of May last, and a short time after I had given in my paper to the Society, I received an obliging letter from Dr. Volborth, which, as it contains information not only corroborative of some statements made in this paper, but also of general interest, I feel that I cannot do better than transcribe.

"St. Petersburg, May 12, 1861.

"DEAR SIR,—According to my promise, I beg leave to inform you that on my return home I found hundreds of Conodonts in the decomposed part of the bone-bed of Ludlow. They have probably undergone metamorphic action, being white, opake, very brittle, and not of so brilliant a lustre as ours. But they are certainly Conodonts, as Mr. Pander has been able to trace in them the same microscopical structure, with the aid of glycerine.

"I found Conodonts, too, at the Isle of Oeland (Sweden), and succeeded in detecting fish-remains at the Isle of Gothland, in marls that coat the natural divisions of the limestones of the Thorsberg, in the south-east of the isle, close to Oestergarn. They belong to those shagreen-scales that are so abundant in the bone-bed of Ludlow (*Thelodus*, Agass.), described by Mr. Pander as *Cœlolepis* from Oesel, and confirm the views of Sir Roderick about the younger age of the strata in the southern part of the Island.

"Dr. Alexander Volborth."

EXPLANATION OF PLATE XVII.

Fig. 1. *Astacoderma terminale*; ×25.
14. *A. terminale*, var. ×15.
2, 3, 4. *A. bicuspidatum* and varieties; ×25.
7. *A. bicuspidatum*, var. ×15.
5 *a*. *A. triangulare*. ×25.
5 *b*. *A. triangulare*, under surface. ×25.
6. *A. triangulare*, var. *diffusum*. ×25.
8. *A. triangulare*, var. *contractum*; ×15.
9. *A. declinatum*; ×25.
10. *A. declinatum*, var. *expanso-acuminatum*. ×15.
11 *a*. *A. undulatum*: vel *declinatum*, var. *expansum*. ×15.
11 *b*. *A. undulatum*, under surface. ×15.
12 *a*. *A. undulatum*, var. *compositum*. ×15.
13. *A. undulatum*, var. *compositum*, under surface. ×15.
12 *b*. *A. undulatum*, var. *compositum*, vertical section, ×25.
12 *c*. *A. undulatum*, var. *compositum*, vertical section, ×60, showing the tubular structure.
12 *d*. *A. undulatum*, var. *compositum*, vertical section, ×250, showing the laminar structure (a few tubuli are injected).
15. *A. serratum*; ×15.
16 *a* & 16 *b*. *A. spinosum*; ×15.
17. *A. remiforme*; ×15.
18. *A. planum*, var. *trituberculatum*; ×15.
19, 20 *a*. *A. planum*, var. *monotuberculatum*; ×15.
20 *b*. *A. planum*, var. *monotuberculatum*, horizontal section, ×250, showing tubuli cut across and arranged in systems.
20 *c*. *A. planum*, var. *monotuberculatum*, vertical section through part of the thickness, ×250, showing the tubuli.

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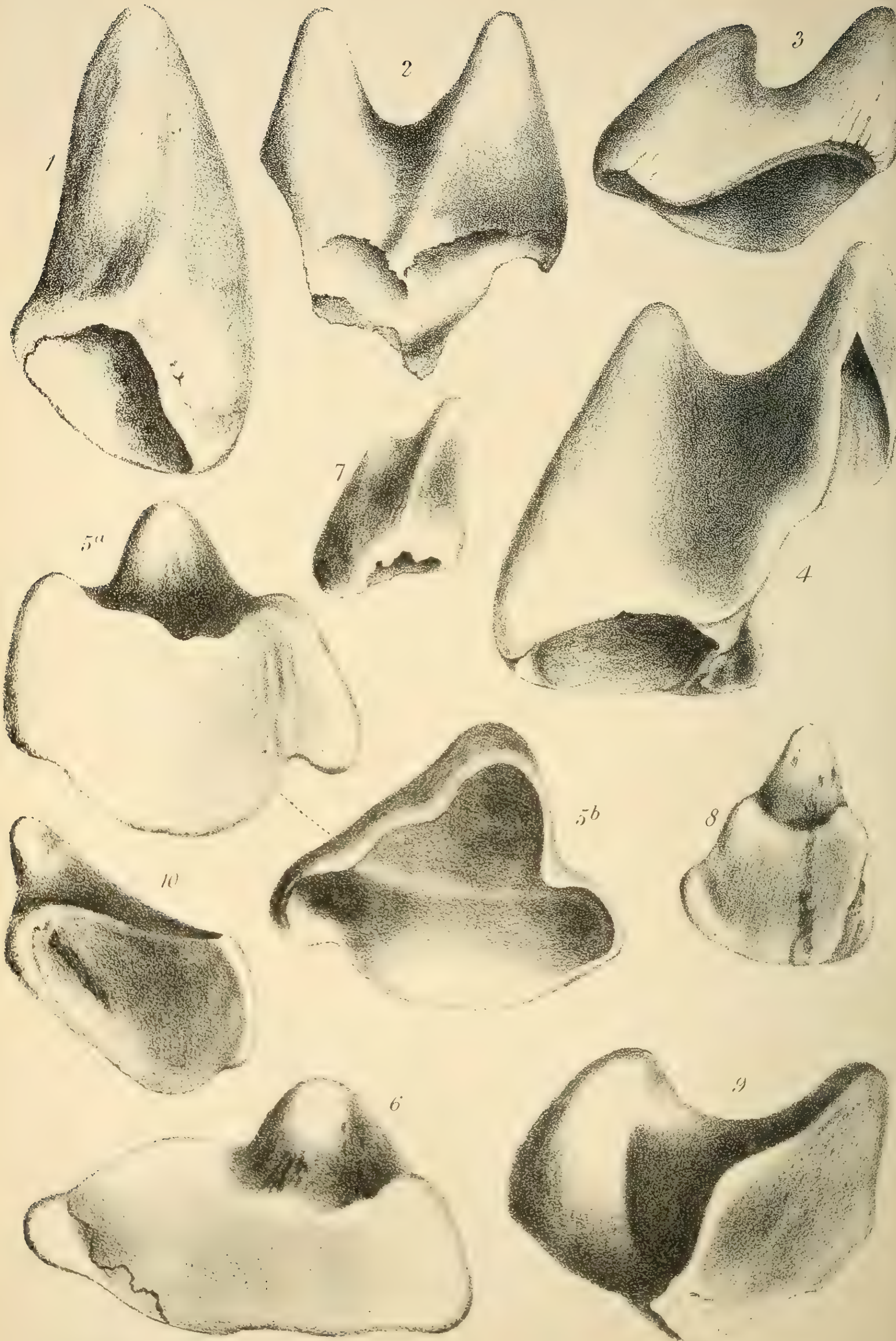
4. *On the* Outburst *of a* Volcano *near* Edd, *on the* African Coast *of the* Red Sea. By Capt. R. L. Playfair, Officiating Political Resident, Aden.

[Communicated by Sir R. I. Murchison, V.P.G.S.]

(*Abstract.*)

At Edd, lat. 13° 57′ N., long. 41° 4′ E., about half-way between Massouah and the Straits of Bab-el-Mandel, earthquake-shocks occurred on the night of the 7th of May or the morning of the 8th, during about an hour. At sunrise fine dust fell, at first white, afterwards red; the day was pitch-dark; and the dust was nearly knee-deep. On the 9th the fall of dust abated; and at night fire and smoke were seen issuing from Jebel Dubbeh, a mountain about a day's journey



From Nature by J.H., on Stone by G.Dewilde

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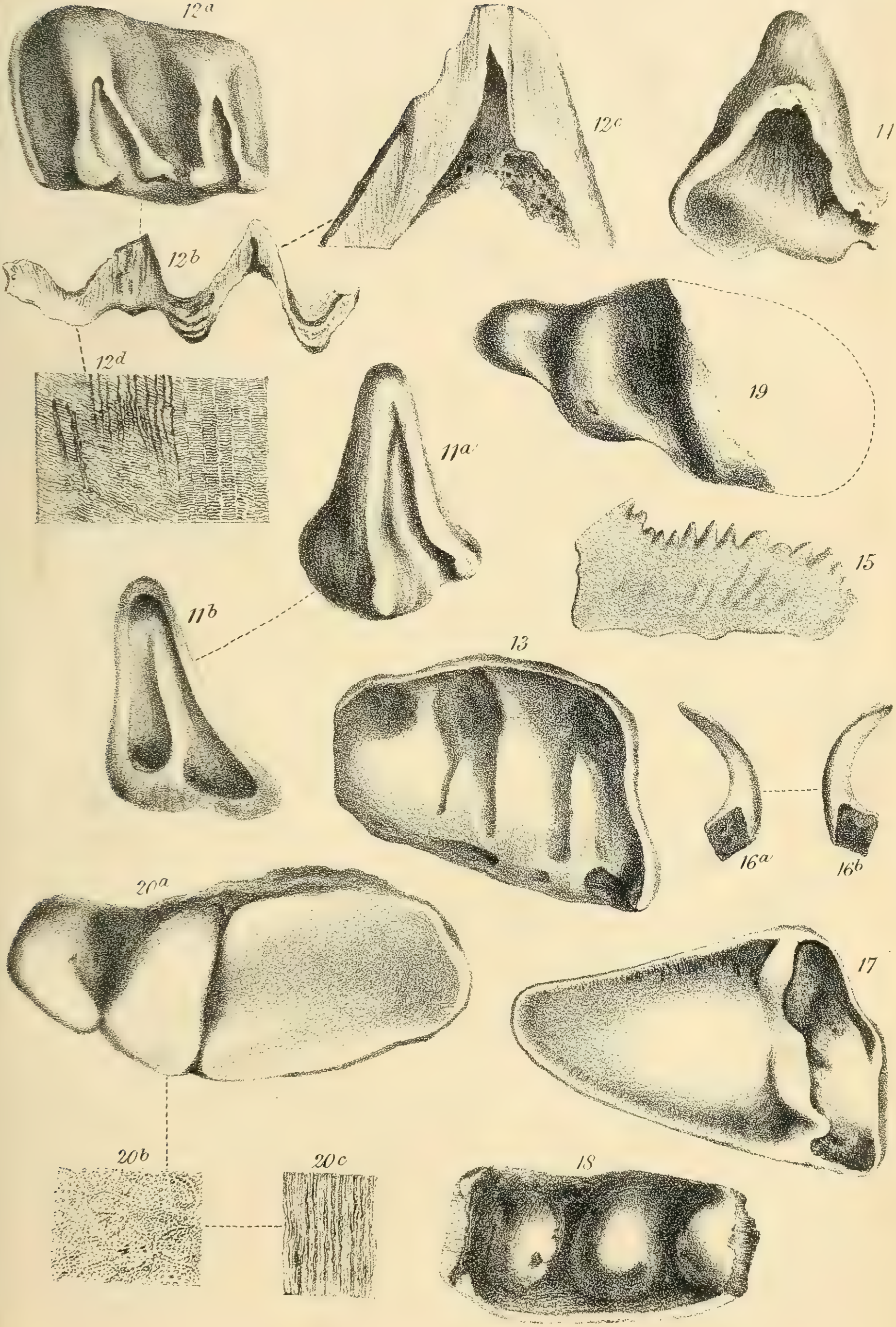

W. West, imp.

BONE BED

From Nature by J. H., on Stone by G. Dewilde

W. West, imp.

ASTACODERMATA THE LUDLOW BONE BED

inland, and sounds like the firing of cannon were heard. At Perim these sounds were heard at about 2 A.M. on the 8th, and at long intervals up to the 10th or 11th. The dust was also met with at sea; and along the entire coast of Yemen the dust fell for several days. Several shocks were felt on the 8th at Mokha and Hodaida.

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5. *Notice of the Occurrence of an* EARTHQUAKE *on the 20th of* MARCH, 1861, *in* MENDOZA, ARGENTINE CONFEDERATION, SOUTH AMERICA. By C. MURRAY, Esq.

[Communicated by the President.]

(*Abstract.*)

AT about $\frac{1}{4}$ to 9 o'clock, the first shock, preceded by a thunder-clap, destroyed the city of Mendoza, killing (it is said) two-thirds of its 16,000 inhabitants. Altogether there were eighty-five shocks in ten days. The land-wave appears to have come from the south-east. Several towns S.E. of Buenos Ayres felt slight shocks. No earthquake took place in Chile; but travellers crossing the Upsallata Pass of the Cordilleras met with a shower of ashes; the pass was obstructed by broken rocks; and chasms opened on all sides. At Buenos Ayres, 323 leagues from Mendoza, and elsewhere, it was observed in watchmakers' shops that the pendulums moving N. and S. were accelerated; those moving E. and W. were not affected.

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6. *On the* INCREASE *of* LAND *on the* COROMANDEL COAST. By J. W. DYKES, Esq.

[From a Letter* to Sir C. Lyell, F.G.S.]

IN the districts of the Kistna and Godavery, the land presents a parallel series of ridges and hollows near the coast, not in relation to the rivers but to the coast-line. These may have been formed by sedimentary deposits similar to what are now taking place on the Coromandel coast. By the strong currents alternately running N. and S., according to the monsoons, lines of sediment parallel with the coast are formed; and by the occasional interference of winds and tides dams are thrown across the hollows, and the latter soon become filled up. These parallel bands of coast-land become, in time, upheaved and more or less affected by atmospheric agencies.

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7. The SECRETARY gave a brief account of the discovery of an exposure of sandstone strata with two bands of clay full of calcareous nodules containing plentiful remains of *Coccosteus*, *Glyptolepis*, and other fishes belonging to the Old Red Sandstone, in a burn about $2\frac{1}{2}$ miles from the Manse at Edderton, Ross-shire, on the south side of Durnoch Firth. This information was contained in a letter from the Rev. J. M. JOASS, of Edderton, communicated by Sir R. I. Murchison, V.P.G.S.

* Dated Kottapaluam, January 17, 1861.

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the Succession *of the* Mammalian Faunæ *in the* Tertiary Basin *of* Vienna. By Prof. E. Suess.

[Proceed. Imp. Acad. Vienna, vol. xxxix. 1860, p. 151, &c.]

The later Tertiaries of the Vienna Basin have experienced so few considerable disturbances that a geologist may easily trace the chief strata filling up this basin, as they follow its margin in concentric zones, with scarcely any interruption. Marine deposits, dipping from every side of the extreme margin beneath the more recent central deposits, are those of most ancient date, although they generally crop out on the highest points of absolute level. These strata include innumerable remains of *Mollusca, Crustacea, Zoophyta,* and *Foraminifera,* described by MM. D'Orbigny, Reuss, and Hörnes, and imbedded in layers of sand, rolled pebbles, limestone, marls, or plastic clay. Great local variety, both in petrographical and palæontological respect, is conspicuous in these strata, although special researches, continued through years, prove beyond doubt that nearly all of them (Sands of Neudorf, Leitha-limestone of Steinabrunn, 'Tegel' of Baden and Voslau, &c.) have been contemporaneously deposited on the bottom of one and the same sea,—their differences not being more striking than those at present occurring in different sea-zones; for instance, of the Mediterranean.

The littoral zone ascends the slope of the hills, marking the ancient shores, to a level of 1300 feet. At this time, the Vienna region had its greatest depth beneath the level of the sea; and, in consequence, the communication between the Tertiary seas of Europe was more open than at any other period: no wonder, therefore, that under favourable climatal circumstances so many species could wander thither from their distant habitats. The occurrence there of forms bearing a Mediterranean or Indian type is a well-known fact. Dr. Hörnes, in his splendid work on the fossil Mollusca of the Vienna basin, also describes species reminding us of those at present living in the West-African seas, such as *Cypræa sanguinolenta, Buccinum lyratum, Oliva flammulata,* &c.

M. Laurent, in his report on the boring of Artesian Wells in the

Sahara*, has remarked, that the portion of this desert lying to the south of the French possessions bears decidedly the character of an ancient gulf, formerly connected with the Mediterranean, in the environs of Gabès. Littoral terraces (the last and most conspicuous of them called "Coudiat el Dohor") exhibit a continuous series of "Falaises," nearly parallel to the original northern outlines of the basin, indicating the successive level of the waters and their gradual diminution. *Cardium edule*, imbedded in sand identical with the sand on the present Mediterranean shores, abounds on the surface in certain places, apparently indicative of shore-lines recently laid dry; the retreat of the waters having proceeded from the Western Sahara (500–600 metres *above* the present sea-level) to the eastern portion of the desert (now 86 metres *beneath* this level in the Schott Melr'ir). Several naturalists have observed *Cardium edule* still living in ponds within the desert, and *Cypræa Moneta* had been asserted to have been taken in the upper course of the Niger†. A wide plain south of the Aures Mountains is covered with deposits characterized as littoral by the presence of *Cardium edule* and an abundance of rolled pebbles. This occurs in a desert, the level of which is not unfrequently lower than that of the nearest sea. M. Buvry‡ gives to the Melr'ir a higher level than M. Laurent does, and indicates the Schott-es-Selam, to the east of it, as the maximum of depression (−85 metres); at the same time mentioning the occurrence between El Faid and the Oasis Mraie'r of depressions of −41, −76, −35, −28, and −20 metres; the ground rising again southward in the direction of Tuggurt.

The facts stated by Caillié, and the lately published results of M. Panet's § explorations, make it probable that analogous traces of comparatively recent marine formation may be followed as far as the Atlantic coast. No hypsometrical measurements of these regions are known at present; the constitution of the desert, however, and the local impregnation of its soil with sea-salt may give some indications in this respect. M. Panet speaks of organic remains and accumulations of broken shells between alternating layers of salt and red clay as occurring in the "Great Sebcha," an extensive region abounding in salt and spreading to the S.W. along the western slope of the Idjil Range in the district of Aderer. It is to be hoped that enterprising travellers may soon procure us a more detailed knowledge of the traces of this line of communication, so important for the study of geological geography, as joining the present Mediterranean exactly south of the point where the submarine ridge, running from south-western Sicily to Tunis, manifests conspicuously its influence on the distribution of marine animals.

It is a fact worth attention, that extensive sea-shores, rising very slowly, are generally covered exclusively with sand, rolled pebbles,

* Bulletin de la Société Géologique de France, 1857, vol. xiv. p. 615.

† See Aucapitaine in Guérin-Méneville's Revue et Magasin de Zoologie, 1859, p. 237.

‡ See Zeitschrift für d. allgemeine Erdkunde, 1858, iv. p. 298.

§ Petermann's Geograph. Mittheilungen, 1859, p. 101.

and remains of strictly littoral shells. An instance of this fact, on nearly as large a scale, is offered by the great terraced plains described by Darwin* as extending from the Rio Colorado to Magelhäen's Straits, and overstrewed with sand, rolled pebbles, and remains of shells identical with littoral species of the present age.

This first period of a communication opened to a marine fauna of prevailing southern (especially Mediterranean) character was followed by an upheaval (proceeding chiefly from west to east), and, consequently, a restriction of the water-surface. Prior to this upheaval, a line of Jurassic shoals† (girded and partly overlain by reefs of *Nulliporæ*), commencing near the northern margin of the great fault which cuts the outer secondary zones of the Alps near Vienna, ran S.W. to N.E. nearly through the middle of the Tertiary sea at this time occupying the basin: subsequently the whole area west of these shoals was laid dry. The water-surface of the Vienna basin was then reduced to about half of its former extent, its highest level not generally rising above 800 feet. This is the epoch of the Cerithian strata.

The palæontological independence of these deposits, as stated by Dr. Hörnes, is a fact of the highest importance for the true knowledge of the Vienna basin. Cephalopods, Brachiopods, Bryozoans, Crustaceans, Echinoderms, and Corals have totally, and Foraminifers almost totally, disappeared in these strata. The marine fauna is notably diminished in consequence of the broken communications with southern seas; and it bears a decidedly East-European character. This same fauna continued to coexist in Hungary with the trachytic eruptions.

Another general upheaval further limited the extent of the water-area, and was followed by brackish and freshwater deposits with *Melanopsis*, *Cardium*, and *Congeria*. The basin being now nearly completely isolated, the fauna became quite different from the preceding one, and the level of the deposits was again lowered. The Tertiaries immediately following these "Congerian Strata" are of fluviatile origin.

It may be considered as a fact beyond all doubt, that during this period the aquatic fauna of the Vienna basin underwent several consecutive isolations, considerable enough to have repeatedly caused the extinction of genera and species. Having been persuaded of this some years ago, I began to follow the traces of the terrestrial animals known to occur in these groups of strata, as I supposed them to be altered by climatal circumstances or by the occlusion and re-opening of communication with other zoological provinces. M. H. von Meyer's well-known researches on the fossil Mammalia from the environs of Vienna have been the bases of my investigation. My honoured friend Prof. C. von Ettingshausen has kindly completed them, by reviewing his researches on the Tertiary Flora of Vienna, and by tracing the distinctive characters of several local floræ within this region.

The remains of the first terrestrial fauna here must be sought for

* Journal of Researches, &c., pp. 201–207: "On South America," chaps. i. ii.

† For instance, near Ernstbrünn, Staats, Falkenstein, and the hills near Pohlau.

in the marine deposits, especially within the Nullipore-banks of the oldest tertiary coasts. Undoubtedly many of the large *Herbivora* of this epoch may (after they had perished) have been carried by the water into the then existing bays, and buried there amid littoral deposits. They are found upon the shores of islets (Leitha Mountains and Central Moravia), certainly of too limited an extent for the existence of such colossal creatures. A *Dinotherium*, an extremely rare species of *Mastodon* (of the family *Trilophodontes*), a large *Rhinoceros* (similar to the *Rh. megarhinus* of Montpellier, but probably of a distinct species), *Listriodon splendens*, H. v. M., a smaller carnivorous animal (of the family *Canidæ*), the very doubtful *Psephophorus*, and a small species of *Cervus* may have existed at this time, especially on the continent west of the bay. *Helix turonica* lived on the sea-shore, especially near Grund. The freshwater shells locally transported amidst marine deposits are different from those of a subsequent period. The terrestrial vegetation of this period, as known at present, consists of remains of drifted wood (*Fegonium*, *Thujoxylon*, *Peuce*, and *Haveria**), and of the strobili of *Pinites Partschi* (Ett.), imbedded in layers in the Leitha-limestone of Mauer, near Vienna. The fauna just described corresponds, as I have previously remarked†, to the fauna of Simorre in France, characterized by *Listriodon splendens* and the *Mastodon* (if identical in species).

The Cerithian strata, although laid open by extensive quarries, have, as far as I know, never shown the least trace of terrestrial Mammalian remains, neither in their arenaceous nor in their calcareous or argillaceous strata. The blue "Tegel" of Hernals and Nussdorf, lately described by me as a deposit formed at a river's mouth‡, contains very complete remains of Seals and Dolphins, fluviatile and paludine Turtles, together with marine Fishes and plenty of land-plants; but, notwithstanding researches continued through years, I never succeeded in tracing in them the evidence of any terrestrial animal. The flora of Hernals, considered by Prof. C. von Ettingshausen to be "nearly related to the floræ of Parschlug and Tokaj, and therefore of decidedly Miocene character," comprises, among other forms, a *Protacea*, a *Laurinea*, and a new species of *Araucaria*. Recent investigations in the neighbourhood of Lauretta, Purboch, and Breitenbrunn have, however, shown that the marine marginal deposits of this district can scarcely be separated from those of the Cerithian period; the two are in many instances exposed in the same quarry. Possibly some few of the terrestrial animals enumerated above among those of the "first fauna" may rather belong to the Cerithian period.

The Congerian strata ("Tegel" of Inzersdorf) provide abundant facts for the study of the contemporaneous terrestrial fauna, charac-

* Unger, Trans. Imp. Acad. Vienna, vol. xiv.; Beiträge zur nähern Kenntniss des Leithakalkes.

† Imp. Geol. Inst. Vienna Annals, in the "Reports of Meetings" for 1858 and 1859.

‡ Vienna Acad. Proc. vol. xxxvii. p. 673; Steindachner, "Beiträge zur Kenntniss d. foss. Fische Oesterr."

terized by *Dinotherium giganteum, Mastodon longirostris, Rhinoceros Schleiermacheri, Acerotherium incisivum,* and *Hippotherium gracile*; in short, nearly all the species known to constitute the fauna of Eppelsheim. *Acerotherium incisivum* and *Hippotherium gracile* seem to have numerically prevailed. Not one species is identical with any of the "marine group," only the *Dinotherium* is still subject to some doubts in this respect. This is the "second fauna" of terrestrial Mammalia. The contemporaneous flora is, according to Prof. C. von Ettingshausen, richer in species than any other in the Vienna basin. Thirty of these species have been described*. The whole flora reminds one of that of Bilin; and is somewhat posterior in age to that of Parschlug.

The "Tegel" with *Congeria* and *Melanopsis* is locally overlain by beds of white quartz-pebbles with external rust-coloured tinge, imbedding here and there layers of fine sand. This deposit ("Belvedere Gravel") is of fluviatile origin. The whole of the Mammals in the "Tegel" of Inzersdorf appear again in it, together with *Sus palæochœrus,* known to occur at Eppelsheim. The nature of the strata was less favourable to the preservation of the terrestrial flora than the clay; silicified stems, however, of *Coniferæ,* and fruits and peduncles of a *Steinhauera* (Ett.), are not of rare occurrence. A *Valvata* and a *Helix* are the only mollusca known at present to occur in these gravels. Notwithstanding the petrographical differences, the mammalian fauna of the "Belvedere Gravels" and the lacustrine plastic clay of Inzersdorf remained identical. The lacustrine molluscan fauna alone became extinct. The flora does not offer sufficient materials for comparison.

The deposits just mentioned are overlain, to my knowledge, by two fossiliferous strata of doubtful contemporaneity, merely local and restricted in their extent. The first of them is a clay, found by M. Kapper, at the Eichkogel, near Mödling (S. of Vienna)†. It contains vegetable remains, which have been referred by Prof. C. von Ettingshausen to the youngest tertiary flora, characterized by the presence of *Salix angusta, Glyptostrobus Oeningensis,* and *Juglans latifolia*; possessing these species in common with the flora of Oeningen in Bavaria.

The other of these deposits is a bed of fluviatile rolled pebbles, differing from those of the "Belvedere Gravel" by being less in size and derived from divers Alpine rocks. No remains of the "Second Mammalian Fauna" have occurred among them. In one case they have been found to include a molar different from that of *Elephas primigenius* (probably of *El. meridionalis*). To these strata may likewise belong a tooth of *Hippopotamus,* preserved in the Imperial Museum of Vienna, and hitherto the only remains of this genus known to have been found within the Vienna basin. These remains may be indicative of a "Third Mammalian Fauna" possibly analogous to that which has recently been called "Pliocene Fauna" (Val d'Arno). As far as I know, this stratum has been stated to occur only within

* Ettingshausen, in Vienna Geol. Inst. Trans., "Die fossile Flora von Wien."

† Annals of the Vienna Geol. Inst. 1859, p. 25.

the immediate vicinity of Vienna itself, in the suburbs of Landstrasse and Reinprechtsdorf; nor can its palæontological independence be asserted yet with certainty.

The uppermost deposit is loam (Loess), with subordinate and occasionally considerable layers of fluviatile rolled pebbles. In this we find the representatives of the "Fourth Mammalian Fauna" (*Elephas primigenius*, *Rhinoceros tichorhinus*, *Ursus spelæus*, *Hyæna spelæa*, &c.). Analogous as the molluscan fauna of this loam is to that of the present times, certain species (*Helix pomatia*, *H. Austriaca*, *H. verticillus*, and *H. ericetorum*) are absolutely wanting in it; and by this negative character the "Loess" may be conveniently distinguished from the loam of less ancient date, frequently covering the lowest portion of our valleys. This "Fourth Fauna" is generally considered to be post-tertiary. Before its appearance a small portion of the Vienna basin had been again invaded by sea-water; and perhaps our present mammalian fauna may hold the fifth place in the whole series.

It is a fact that several hundreds of the marine species of the Vienna basin coeval with the "First Mammalian Fauna" are still existing, chiefly in the Mediterranean, while the mammalian fauna has undergone three or four changes.

The more I recall to memory these chief results of several years' investigations, the more I see how each group of terrestrial or aquatic animals is imbedded in strata different in petrographical character, in extension, and in level, every one keeping up its independence, while the terrestrial mammals offer in some degree representatives of the precedent and subsequent faunæ. The more I attend to change of coast-line, the transition of marine to brackish, lacustrine, and finally fluviatile deposits, and the changes in the course of rivers, manifested by the diversity of the gravels, the less I feel the necessity of adopting an hypothesis as bold as is that of a "Species-life" (Artleben). The repeated extinction of these organized beings appears to me rather as a necessary consequence of the change of external conditions, as they may be traced in the present case. Within the Vienna basin, *communication* has prevailed with respect to terrestrial animals, and *isolation* as far as aquatic animals were concerned.

The terrestrial flora has equally undergone more than one change; and possibly the repeated extinction of mammals may have been a merely secondary fact, connected with these changes of vegetation.

Among others, the fossil fauna of Pikermi, near Athens, entitles us to suppose that at least one or the other of the above-mentioned mammalian faunæ was not spread uniformly over the whole surface of Europe, as it exists at the present time. [E. S.]

On PEAT *and* BROWN-COAL. By Professor POKORNY.

[Proceed. Imp. Geol. Instit. Vienna, April 17, 1860.]

PROF. POKORNY has lately visited the principal Peat-bogs of the Austrian Empire, and published the results obtained by him in the 'Transactions' of the Vienna Zoologico-Botanical Society, in whose

Museum he deposited a collection of 130 specimens of Peat. The varieties of this substance may be distributed into four groups:—(1.) Vegetables in progress towards their conversion into peat; (2.) Peat in its proper sense; (3.) Carboniferous resinous substances; (4.) Half-peats. To the first group belong the isolated patches of *Carex stricta,* rising above the level of the surrounding moors, and which in Hungary are known under the name of "Zsombek," the thin layers of peat covered with moss, grass, or rushes, and the fragments of wood included in peat. To the second group belong the moors of the plains overlying inorganic strata, and impregnated with earthy and saline particles by the waters irrigating them, and the mountain-moors, or high moors overlying—sometimes at a considerable depth—the detritus of forest-, heath-, or moor-vegetation, and irrigated by water free from inorganic substances. The plain- or rush-moors produce brown, fibrous, or amorphons peat, of dry consistence, and, on their surface, a variety (meadow- or pitch-turf) of darker colour and more compact structure, but more mixed with other substances. The peat of *mountain*-moors is purer; its specific weight (not compressed) varies between 0·5 and 0·8; and it is especially adapted for the heating of boilers and for metallurgical purposes. An earthy variety from Zips (N. Hungary) bears great resemblance to the "Umbra" of Cologne. The "Dopplerite" of Aussee (Styria) and analogous substances from the peat-bogs of Switzerland and Berchtesgaden, described by MM. Deicke and Gümbel, constitute the third group. The half-peats (fourth group) are mixed with notable proportions of inorganic substances, and, although capable of slow combustion, cannot be ranked among peats if this portion amounts to 30–50 per cent. [COUNT M.]

On the GEOLOGY *of* WESTERN GALICIA. By M. FOETTERLE.

[Proceed. Imp. Geol. Instit. Vienna, April 24, 1860.]

LOWER Secondary deposits, connected on the W. and E. with those of Hungary (Red Sandstone, Triassic Dolomite, Kössen and Adneth strata), appear only on the northern slope of the Tatra mountain-group, resting on granite and partly overlain by Nummulitic limestone and menilite-slate. A powerful range of Triassic limestone runs northward of the Carpathians from Rozagnik to Innwald, stretching E. and W. into Hungary; it is associated with Liassic and Neocomian marls.

The Neocomian beds (Hoheneger's "Teschen Slates") extend W. and E. from Biala (Silesia) to Tarnow (Galicia), and S. of Biala in the same degree of development. The Carpathian Sandstone prevails within the region in question. The lowermost, non-fossiliferous, strata are Cretaceous. A Fucoid with a spiral axis, like *Fucoides Brianteus,* and common to the Gosau-marls and to the Fucoid-marls near Vienna, occurs in this sandstone near Neumarkt.

The upper Nummulitic (consequently Eocene) strata of the Carpathian Sandstone are far spread about Saypath, Tordanow, between Neumarkt and the Tatra; they are overlain by a thick mass of sandstones, alternating in their basal portion with black slates, containing (like the menilite-slates of the uppermost Eocene) fragments of *Lepidopides leptospondylus*, Heck., *Meletta longimana*, Heck., &c. They occupy the valleys and depressions, and are highly impregnated with bitumen, which is exploited as naphtha in several localities. The overlying coarse-grained sandstones, extending south-eastward to Eastern Galicia and Bukowina, occupy the higher horizons. The greater portion of the argillaceous iron-ores worked in Eastern Galicia are connected with the above-mentioned black slates. Upper Eocene Tertiaries, abundant in salt, gypsum, and sulphur, are confined to a narrow band along the northern extreme edge of the Tatra, and generally disappear beneath a great deposit of loam (Löss). Eruptive rocks (trachyte and diorite) appear on a small scale in some few isolated localities. [Count M.]

On Piddingtonite, *and a* Meteorite *from* East India. By Director W. Haidinger.

[Proceed. Vienna Imp. Acad. Sciences, June 8, 1860.]

A collection of Indian Meteorites that came into the possession of the Imperial Museum of Vienna (in June, 1860), by way of exchange, through the good offices of Messrs. Oldham and Atkinson, contains specimens from Allahabad (Futteh-poor, Nov. 30th, 1822), Shalka (Nov. 30th, 1850), Segowlee (March 6th, 1853), Assam (1846, found by the late Mr. Piddington), Pegu (brought by Mr. Oldham from Ava), and a fragment of the still problematic lumps of iron, weighing 156 lbs., found on the Kurrak-poor Hills, near Monghin, on the banks of the Ganges. The first specimen examined (from Shalka, 1850) has proved to be nearly entirely composed of a nondescript mineral substance, which Director Haidinger has named "Piddingtonite," in honour of the late Mr. Piddington, Curator of the Calcutta Museum of Practical Geology, known to the scientific world by his able researches on Cyclones, and to whose exertions we are indebted for the preservation of the still extant fragments of this originally very large Meteorite, and for its first scientific investigation in the 'Journal of the Asiatic Society of Bengal' (vol. xx. 1852). *Piddingtonite* is of ash-grey colour, more or less fine-grained, very fragile, although of considerable hardness (6·5 Mohs, or between felspar and quartz), more or less translucid, of oil-like brightness, imperfectly cleavable in two directions intersecting at angles of about 80° and 100°, and without magnetic action.

The whole meteorite is of a breccia-like aspect, interspersed with minute grains and incomplete crystals of black chromate of iron; its crust is dark-brown, and nearly opaque. About 9 lbs. weight was saved for the Calcutta Museum, the rest having been taken by the people of the surrounding country. The fall, with the usual phenomena of light and detonations, took place three hours before sunrise, in a clear starry sky: the stone coming down in a direction of S. to N., and under an elevation of 80°, penetrated 3 feet deep into the soft ground of a rice-field. When dug out next morning, it was quite cool; the surrounding ground, however, had evidently been altered by the action of heat. The original size could not be perfectly ascertained; certainly the breadth and length of the stone were not less than one foot; its height was probably still more: fragments were found at 3 feet depth, and others were scattered on the surface within 20 feet circumference. [COUNT M.]

On the METEORIC IRON *from* NEBRASKA. By DIRECTOR W. HAIDINGER.

[Proceed. Vienna Imp. Acad. Sciences, December 13, 1860.]

A FRAGMENT of a specimen of this iron preserved in the Museum of St. Louis (U.S.), arrived at Vienna (as promised by Mr. Nath. Holmes, Secretary of the St. Louis Academy) on October 30, 1860, by the care of the Smithsonian Institution. The fragment, weighing 1 lb. $4\frac{5}{16}$ ounces, was cut in two pieces parallel to its longitudinal axis, and the cut faces were polished. One of these pieces, $2\frac{1}{2}$ inches in length, 2 inches in breadth, and 10 lines thick where it is thickest, shows on one side the original surface, nearly even, with very shallow depressions confined by rounded edges, and with some trace of the dark-brown crust still preserved in the concavities. The weight of this piece is $8\frac{9}{16}$ ounces. The plane of the cutting shows strings of whitish colour indicative of crystalline structure ("Widmannstetten's figures"); and, by a lucky chance, the direction of the cut fell nearly parallel to the plane of an octahedron. The "stripes" intersecting, at angles of 60° and 120°, the triangular and rhombic "intermediate areæ" between "projecting borders" of Schreibersite are conspicuous over the whole surface, after having been submitted to the etching-process, and keep a constant and perfectly parallel disposition. It cannot, therefore, be doubted that this iron went through a process of crystallization during a period as yet unmeasurable.

The cleavage or lamellar structure parallel to the planes of the cube, as it appears on the meteoric iron of Hauptmannsdorf, near Braunau (July 14, 1847), is not conspicuous on the Nebraska iron; nor does the latter show the damask-like crystalline patterns of the irons of Bohumilitz and Basin. It exhibits rather the genuine "Widmannstetten's figures," such as are conspicuous on the meteoric irons of Elbogam, Agram, and Aurange; coming next in texture to the large 1·635 lb. mass from Red River (Louisiana), or to the iron from Texas (Vala Colluja) described and autotyped in Silliman's 'American Journal.' The white zigzag lines, conspicuous in the figure, are produced by crevices in the crystalline substance, parallel to the planes of the octahedron. The white round spots indicate the places where the action of the acid has penetrated to a greater depth around central particles of sulphuretted iron.

The second piece obtained by cutting is of 10 ounces weight, nearly 4 inches in length, $2\frac{1}{4}$ in breadth, and $\frac{1}{4}$ to $\frac{5}{8}$ inch in thickness.

An excellent lithographic figure of the Nebraska iron, in the 'Transactions' of the St. Louis Academy, vol. i., shows it from the side which may be supposed to be that opposite to the direction of the meteor during its course through the atmosphere, as it presents a great number of such shallow depressions as are so conspicuous in the Meteorite of Gross Divina, which fell July 24, 1837. (See Haidinger, 'Proceedings' Vienna Academy, vol. xl. 1860, p. 528.)

According to Mr. N. Holmes, the iron in question was found on the right shore of the Missouri, in the Nebraska Territory, 20 miles from Fort Pinoon (44° 19′ N. Lat., 100° 26′ W. Long. from Greenwich), in 1857, by Mr. C. P. Chouteau, who in the spring of the following year presented it to the Academy of St. Louis. When first found, its surface was but very little altered by rust.

Mr. A. Prout analysed it, and found

Iron	94·288	*per cent.*
Nickel	7·185	,,
Magnesium	·650	,,
Calcium	·350	,,
Sulphur	a vestige	
	102·473	

No trace of cobalt, manganese, chrome, or any other substances besides the five named above could be made out. Perhaps the "projecting borders," supposed above to be Schreibersite, may prove upon closer examination to consist of a phosphuret of iron and nickel. The specific weight of the whole, at a temperature of + 12°, is 7·362; it may be supposed to be somewhat higher in smaller fragments, as superficial crevices seem to indicate the existence of internal solutions of continuity. [COUNT M.]

On the LIASSIC FLORA *of* TRANSYLVANIA. By FRANZ VON HAUER.

[Proceed. Vienna Imp. Geol. Instit., March 13, 1860.]

A COLLECTION of plants made by Prof. Meschendörfer, of Kronstadt, from a black slate at Holback and a light-yellow micaceous quartzose sandstone at Neustadt, in the Siebenbürgen, which are regarded as equivalent to the "Gresten Strata" and of Liassic age, consists of the following species:—

a. From Holback.

- Cyclopteris, sp. (?); fragments of a very large species.
- Anthopteris meniscoides, *Brongn.* (Found also near Bayreuth.)
- Tæniopteris vittata, *Brongn.*: not well preserved. (Found also in England.)
- Zamites Schmiedeli, *Sternb.*: badly preserved, but distinct. (Found also in Franconia and in the Liassic Coal of Steierdorf.)
- Zamites, sp. (or Pterophyllum?); in fragments.
- Pterophyllum rigidum, *Andr.* (Also found at Steierdorf.)
- Cunninghamites sphenolepis, *Braun.* (Found also in Franconia and at Fünfkirchen in Hungary.)

b. From Neustadt.

- Zamites Schmiedeli, *Sternb.* A large specimen, beautifully preserved.

Zamites, n. sp. (Also found at Steierdorf and in the Venetian Alps.)

Pterophyllum rigidum, *Andr.*

This flora may be considered as identical with that of Steierdorf in Banat, and consequently with that of the Lettenkohle of Bayreuth, belonging to the horizon of the "Bone-bed." [Count M.]

On the Fossil Shells *of the* Freshwater Tertiaries *of* Bohemia. By Prof. A. E. Reuss.

[Proceed. Vienna Imp. Acad. Sciences, June 8, 1860.]

The molluscan species at present known to occur in the freshwater tertiary limestones of Bohemia amount to 68, distributed as follows: —*Cyclostomacea* 1, *Aciculacea* 2, *Helicinea* 50, *Limnæacea* 12, *Cycladida* 3. Among the 50 *Helicinea* there are 24 species of *Helix*, 3 of *Bulimus*, 6 of *Glandina*, 7 of *Pupa*, and 7 of *Clausilia*. The prevalence of *Clausiliæ* (nearly all of new species) gives a particular feature to this fauna, as they abound in it more than in any other locality of analogous nature. Among them, *Clausilia vulgata* and *Cl. peregrina*, Reuss, are already described: the new species (*Cl. tenuisculpta*, *Cl. denticulata*, *Cl. polyodon*, and *Cl. amphiodon*) are all very nearly related to the present European forms. A shell of the family *Limnæacea* constitutes a new generic type, named "*Acrochasma*" on account of the structure of its shell. The only known species (*Acrochasma tricarinatum*, Reuss) has a trilateral pyramidal shell rounded below in its whole amplitude, with one posterior concave, and two lateral slightly convex planes, ending upwards in an acute reflected apex, beneath with a longitudinal aperture through the shell, which in its living state seems to have been covered with an epidermis. The new genus stands next to *Ancylus*, and may be considered as a freshwater representative of the marine genus *Fissurella*.

Among the 68 species from the Bohemian freshwater limestones, 15 (or nearly $\frac{1}{4}$th) are identical with those from the analogous deposits of Hochheim, in the Mayence basin. Eleven other species bear such a resemblance to some from the same locality that they may be said to represent them. From these facts it may be concluded that the Bohemian and the Mayence freshwater limestones were coeval.

[Count M.]

On the Geology *of* South-Eastern Hungary. By Prof. Peters.

[Proceed. Vienna Imp. Acad. Sciences, June 8, 1860.]

The mountainous district of Bihár, well-known for the rich metalliferous veins and the fine mineralogical specimens of Rézbánya, lies enclosed between the metalliferous mountains of Banat and N.E. Hungary, the Transylvanian Highlands, and the great Centro-Hungarian plain. Its stratified deposits, save some peculiarities in their development, are the same as at Banat: its structure and connexion, as a whole, with its main range, its intervening hills, and its partly isolated eruptive masses remind one as much of the uniform mica-schist ranges in the Köros, Számos, and Berettyo valleys, as of the masses around Nagybánya. The red slates and sandstones (probably "Old Red") and the Carboniferous strata immediately overlying the mica-schists of the Banat are again met with in the Bihár mountain-group. The Liassic limestones and sandstones (although non-carboniferous) are well developed and identical with the Alpine "Gresten strata." Triassic strata and those intervening between Trias and Lias seem to be totally wanting.

Jurassic deposits intimately connected with Neocomian strata are represented by Carpathian Cliff-limestones and (probably) "Klaus strata." The tertiary Congerian clay is of general occurrence as far as the foot of the high mountains; Cerithian strata nowhere advancing so far upwards. The Neogene deposits of Bihár agree exactly with those of Central Hungary. Among the massive rocks, a stratified euritic porphyry with remarkable tuffs, porphyroid rocks of less remote date, and a particular variety of syenite of relatively very recent date are conspicuously prevalent. All these rocks have acted most powerfully in the disturbance of strata and in the distribution of metalliferous minerals. A large mass of trachyte and an eruptive rock of the variety named "Rhyolite" by Baron Richthofen have been observed. [Count M.]

On the Metalliferous Deposits *in* S.E. Hungary. By Prof. Peters.

[Proceed. Vienna Imp. Acad. Sciences, July 12, 1860.]

The rich deposits of lead- and copper-ores, exploited in the district of Rézbánya, are not veins, as generally supposed, but massives, associated with clastic rocks and intercalated into Jurassic and Neocomian strata. The eruptive rocks (syenite and greenstones) connected with them are concerned in the origin of these metalliferous deposits; their violent action having caused disruptions, into which the ores were subsequently deposited. At a certain depth ores are found together with rocks produced by contact, and mineralogically analogous to the wollastonite-rock of Banat, and in some sort with those of Monzoni (S. Tyrol), Mount Vesuvius, &c.

The magnetic iron-ores occur, as in Banat, at the contact of syenite and Jurassic limestone, and are of great importance, especially near Potrosz, although still neglected for want of capital. More than 60 mineral species occur in the mining district of Rézbánya. Among them, simple and binary compounds of tellurium with silver, copper, and arsenic, buratite (Delesse), associated with smithsonite and calcareous spar, linarite and caledonite, connected with carbonate of lead and galena, brochantite (not stanniferous, as Prof. Magnus thought it to be), a new hydrosilicate of magnesia, potash, and alum (erroneously named agalmatolite), and a hydroborate of soda and magnesia (very probably isomorphous with the boro-calcite of Iquique), appearing in the shape of microscopical acicular groups in a granular limestone modified by contact, deserve particular attention. [Count M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the Formation of the VOLCANO *of* JORULLO, MEXICO. By M. H. DE SAUSSURE, of Geneva.

[Bulletin de la Société Vaudoise des Sciences Naturelles., 1859, No. 45, vol. vi. pp. 195–197. (Séance du 22 Juin, 1859.)]

IT is, this very year, precisely a century since the fine valley of Jorullo witnessed the transformation of its surface, previously covered with plantations of indigo and sugar-cane, into a barren sheet of stony lava. This catastrophe had for one of its results a perfectly characterized volcanic mountain, which suddenly sprung up on the surface of the globe, with unexampled rapidity and grandeur of proportions.

The importance of this phenomenon in a geological point of view is great, from the conclusions to which it has been supposed to lead. Too much attention therefore cannot be given to the study of its mode of action, especially as the latter has been wrongly interpreted, and has been applied to support theories of an absolutely unfounded character.

Humboldt, who visited the volcano only forty-three years after its first appearance, considered it as the consequence of upheaval (*soulèvement*). According to him, the immense sheet of lava which surrounds the mountain is the result of a softening of the pre-existing surface-soil (*sol*) by gases, and its inflation from beneath like a bladder. The border of this sheet of lava is, according to him, the broken edge of the kind of table which the subterranean action thus heaved up. This opinion served as an argument in favour of the theory of "Craters of Elevation" of von Buch, which ascribes to other volcanos the same origin. But the very first inspection of the locality suffices to show that such an opinion cannot be sustained in the present state of the science. In my opinion Jorullo is not the result of any kind of elevation, but has been produced solely by means of *eruption* and *accumulation*. The sheets of lava, called "Malpais," are nothing else than vast outflows of incandescent matter, which have lined the whole valley, filling its cavities and forming promontories, just as a mass of molten lead would spread when poured on an uneven surface. The edges of the "Malpais," raised from 30 to 80 feet in height, are not a section or broken edge of an elevated tract, but only the lateral or terminal borders of currents of lava. The cone which forms the mountain of Jorullo itself is the simple result of the heaping up of cinders and scoriæ ejected by the principal orifice of eruption.

The volcano of Jorullo, in fact, is composed—

First, of the sea of lava which resulted from several repeated outbursts of lava from fissures, which outbursts, successively lessened in the area covered by each, as it overflowed the preceding one, formed four distinct terraces or steps, one higher than the other.

Secondly, of a central cone raised above these lavas after they had ceased to flow, by the gaseous eruptions.

Thirdly, of one great and last current of lava which flowed from the summit of the cone and encircled its base. This current was due to the emission of lava after the gaseous explosions which formed the cone had terminated.

Lastly, the remnant of lava which remained in the hollow of the cone, as in a basin, by degrees sank within it as the subterranean action ceased and the lava-column in the chimney subsided, from which resulted a series of concentric ruptures and subsidences which form the vast cavity of the crater.

Besides the principal cone, there is also a series of small cones arranged on one line, which are only heaps of ejected scoriæ and ashes, and do not appear to have produced any lava. Their arrangement shows the eruption to have taken place from an axial fissure running N.–S. But there is no trace of the elevation (*soulèvement*) of the beds along this axis, which proves that the volcanic pressure from beneath had not broken up the surface-beds, but only forced an exit through some *fault* in them for the escape of the liquid and fluid matters erupted.

Other small cones of ashes are scattered about at some distance from the principal one. It will be seen from what has been said, that the principal cone rises from a base of lava already high. In fact, the surface of the "Malpais" rapidly rises from its edges to the foot of the cones. This highest point forms, according to Humboldt, the summit of the raised "bladder" of lava, and of the "upheaved" plain. I do not think its structure is to be viewed in any such light. The imperfect drawing of Jorullo published by the illustrious traveller propagated his error among other geologists. The surface in the midst of which the volcano broke out, was not a "plain," as Humboldt erroneously calls it, but a very uneven valley; nor was it in the bottom of this that the fissure opened whence issued the basaltic lavas which covered the neighbouring surfaces, but on the eastern slopes of the valley, and in a direction parallel to its axis, so that the great height of their culminating portion is due in part to the previous height of the surface beneath, and explains itself without the necessity of supposing any upheaval.

It should be added that the highest portion of the "Malpais" was still further raised by the superposition of several successive sheets of lava, which did not reach the outer limits.

It is evident, then, that the volcano of Jorullo has been formed in no degree by upheaval, and that its phenomena, far from pleading in favour of the upheaving action of the volcanic force, show, on the contrary, that the most powerful volcanic outbursts can take place without the slightest derangement of the superficial beds.

[G. P. S.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the Existence of Three Divisions *in the* Devonian Rocks *of the* Lower Loire. By Dr. Bureau.

[Bulletin de la Société Géologique de France, 2me série, vol. xvii. pp. 789–796.]

The Devonian rocks of the Lower Loire rest on metamorphic slates, which graduate downwards into mica-schist, finally resting on the granite of La Vendée. The whole mass is divisible geographically into a northern development of grits, coal-beds, and conglomerates, and a southern one of clay-slates with associated limestones.

1. Lower Devonian. These form the southernmost beds, and contain *Pleurodictyum problematicum* and *Leptæna depressa*. The limestones contain Corals, of which *Calamopora Goldfussii* is the type.

2. Middle Devonian. Proceeding northwards, a band of slaty limestone is met with, sometimes pink and in other places black, characterized by *Stringocephalus Burtini*.

3. The upper schists are charged with numerous Brachiopods, described by Dubuisson in 1830. In the same beds Dr. Bureau discovered fragments of Plants. He doubtingly separates these schists from the Middle Devonian on palæontological evidence. A gradual change carries this slaty rock into the upper grits, which constitute, with subordinate coal-beds and conglomerates, the northern exposure of the Devonians. The limestones occurring here are charged with *Terebratula cuboides*, *T. pugnus*, &c. The grits and coal-beds alternate four or five times, in parallel stratification. The flora of the coal-beds differs from the great Carboniferous flora, although there are some species common to both. Ferns are represented by *Sphenopteris*.

The slates containing *Spirifer Verneuilii* (which the French geologists always class with Devonian rocks, although our Dublin neighbours label them as Lower Carboniferous) are entirely absent in this district.

Dr. Bureau's expected work on the details of the district will doubtless aid in the construction of a true Devonian flora, and contribute to the determinate classification of an interesting series of rocks which at present are occasionally claimed as Carboniferous.

[S. R. P.]

On the Liassic *and* Keuperian Formations *of* Savoy. By Alphonse Favre.

[Mémoire sur les Terrains Liasique et Keupérien de la Savoie: par Alphonse Favre, Professeur de la Géologie à l'Académie de Genève. (Geneva, 1859, 4to, pp. 92, with 3 plates.) Extrait du tome xv. des Mémoires de la Société de Physique et d'Histoire Naturelle de Genève.]

On the Contrariety *observable in the* Alps *between the* Stratigraphical Succession *of the* Beds *and their* Palæontological Contents; *with an Additional Example of this Contrariety.* By Scipio Gras.

[Considérations sur l'Opposition que l'on observe souvent dans les Alpes entre l'ordre stratigraphique des couches et leurs caractères paléontologiques, suivies d'un nouvel exemple de cette opposition. Par M. Scipion Gras, Ingénieur en chef des Mines. Annales des Mines, 5me sér. vol. xviii. 4e livr. de 1860, pp. 17–54.]

The great interest which just now attaches to the study of Alpine geology arises from its striking exhibition of apparent exceptions to the established order of superposition.

M. Favre thus states the case:—

"In the Tarentaise, Coal-plants and Oolitic fossils appear to be associated together. Controversy as to this has lasted for thirty years, and affects the very foundations of palæontology.

"In the valley of Chamouni, Jurassic limestone is seen dipping beneath crystalline rocks.

"In the valley of Reposoir, rocks containing *Ammonites* and *Belemnites* rest on Nummulitic beds.

"In the hills of Coux and Golèze, Liassic or older rocks rest on Nummulitic strata.

"At the base of the Môle, the strata are Neocomian by fossils and Jurassic by position."

Two leading theories have been advanced respecting these and similar cases. One, which is well represented by M. Favre in the work referred to, is that they are due to enormous folds and faults; the other, advocated by the mining engineer in chief, M. Scipio Gras, in the second work, that they are actual local exceptions.

M. Favre says, referring to the instances above quoted:—

"In spite of these observations, I neither believe in the contemporaneity of Coal and Jurassic fossils, nor in the inferiority of Ammonite-beds to Nummulitic, nor that the latter are older than the Lias, still less that the Neocomian were anterior to the Jurassic, or Tertiary rocks to Secondary."

A problem of so much interest to geology, when thus clearly stated, and illustrated by carefully delineated surveys, is well worth attention. The two publications before us, especially the former with its admirable sections, furnish ample materials.

M. Favre first describes the rocks of Meillerie and of the Dranse. They form part of the great Liassic chain stretching from the shore of the Lake of Geneva to the Arve, from Meillerie to the Môle. They consist of a quadruple series, which, according to our author, is folded four times on or, rather, within itself. The lowest group is the Toarcian,—marly beds with cement-stones; characterized by *Ammonites Aalensis*. 2. Liassic and Sinemurian. 3. Kössen beds (*Avicula contorta* beds). 4. Dolomitic cellular limestone, of large development and constant position throughout the Alps, called "Cargneules." The last two are classed with the Keuper; the first two with the Lower Jurassic or Liassic. The picturesque gorge of the Dranse exhibits the same series; but the ends of the plications are here apparent. The 4th group attains great thickness, and contains large masses of gypsum at Feterne and Epine.

Associated with the latter are bituminous coal and jet. Downwards it extends into the representatives of the saliferous red rocks of the Jura.

M. Favre has a highly interesting chapter on the intermingling of fossils in these rocks; he makes out numerically that some few species are common to the Lias and the Trias, and a larger proportion common to more than one stage of the Lias. He then describes various other localities in which the Kössen beds are surmounted by Liassic strata, especially at Tanage, where both are underlain by anthracitic deposits. He then describes extensive sections across the Trias, Lias, and Jura. Mont Blanc is enveloped in Keuper rocks (*Marnes irisées*); and although the discovery of instructive sections was as difficult to him as to Mr. Ruskin, yet he concludes—"The beds are here found in an inverted order of superposition. This fact, so long doubted, appears to me to be completely proved by the relative position of the gypsum-beds and the Triassic 'cargneules.'"

He next dwells on the correlation of the Lias of Savoy with formations of the same age elsewhere, and on the extent of their metamorphism.

We now turn from this highly satisfactory contribution to science, to the second, which will also invite investigation and repay perusal.

M. Scipio Gras first lays down his theory and refers to existing instances in its support, and then cites a new proof.

He states his view to be—that the causes usually assigned for the abnormal condition of the Alpine strata are wholly gratuitous, and that these strata were actually deposited in the order in which they now appear,—that they have not been reversed,—that they constitute a special palæontological province, originally differing from others by reason of the enormous local contemporaneous disturbances.

His new case is taken from the valley of Entremont, where beds containing White-chalk fossils are actually interstratified with others of Neocomian age.

The geology of this district had previously been described by MM. Favre and Lory, who had attributed the phenomena to reversals and faults; but M. Gras by a minute survey has been led to believe that this is impossible, and that the intercalation of the two systems here is real.

He concludes by stating that, "As these great differences, belonging not only to the fossils, but to the character and disposition of the rocks, are not peculiar to the Upper Chalk alone, as compared with that of other countries, and of which we find parallel cases, though not so well marked, in the rocks of Dauphiné, it is probable that these numerous anomalies spring from a common source,—that is to say, the former existence of special geogenic centres, under the influence of which the Alps were formed, and which render them a geological province altogether unique." [S. R. P.]

Studies *on the* Metamorphism *of* Rocks. By M. Delesse.

[Etudes sur le Métamorphisme des Roches, par M. Delesse. Ouvrage couronné par l'Académie des Sciences. Paris, 1861.]

The author having in a previous essay (Annales des Mines, 5 serie, t. xii. 1857, p. 80) treated on special or contact metamorphism, restricts himself in the present memoir to general or normal metamorphism. This work being of considerable length and replete with facts, space will only permit of a general outline of the more important conclusions. His definition of metamorphism is, the passage from the fragmentary and amorphous state in which stratified rocks are usually deposited, into one more or less crystalline; which change may take place in rocks of every description. According to this definition, some rocks must be considered metamorphic which the majority of geologists have not looked upon as such,—as, for example, deposits of clay in the midst of which crystals of selenite have been subsequently developed.

The plan adopted by M. Delesse is, first to investigate and describe the nature of various rocks as now formed or as they occur in an unaltered condition, and then to consider what changes have taken place when they are metamorphic and crystalline. He thus in Section 1 treats of beds and veins of minerals having a metallic basis, as iron, manganese, zinc, copper, tin, &c.,—the general conclusion being that, "when subjected to general metamorphism, their structure becomes more crystalline. As to their chemical composition, it is sometimes modified (by removal or addition of constituents); and sometimes, on the contrary, it remains the same" (p. 23).

In Section 2 he considers the metamorphism of erupted rocks, and suggests that the absence of rocks identical with modern volcanic products, from crystalline schists, may be explained by supposing that they too have been altered. Thus, for example, the operation of general metamorphism may have changed trachyte into granite, and trappean rocks into dolerite. Nevertheless he does not suppose that all plutonic rocks have been produced in this manner, and shows that they were often formed under the conditions which brought about general metamorphism, and therefore, if again subjected to the same influence, would be only slightly altered.

Section 3 treats on the metamorphism of stratified rocks, and in the first place, on that of coal and other combustibles. The changes which they have undergone when subjected to general metamorphism are precisely similar to what are met with when beds of coal are in contact with erupted non-volcanic rocks. There has been a gradual elimination of the oxygen and hydrogen, and there is a gradual passage from wood, lignite, and coal, to anthracite and graphite; which latter mineral, according to the author, is always associated with rocks that have been subjected to an energetic metamorphic action.

In treating of the various accumulations of sulphate of lime, though, as already mentioned, he looks upon the development of crystals of gypsum in clay as a case of genuine metamorphism, he clearly points out that some highly crystalline accumulations of gypsum were probably deposited as such, and are therefore in a normal condition. He calls attention to the development of mica in some of the metamorphic gypsum of the Alps, which is of interest as showing that that mineral may be formed at a temperature no higher than 120° C. (248° F.), at which gypsum passes into anhydrite. In explaining the origin of quartzite, the author specially refers to those sandstones which consist of minute crystals of quartz, either deposited as such or formed *in situ*, showing that, in some circumstances, quartz may crystallize when other rocks associated with it have undergone no change.

It would render this extract too long if anything more than a general outline were to be given of that part of the essay treating on the changes which have taken place in the various kinds of sandstone and clay. The author considers the case of sandstone, clays, magnesian clay, marl, argilite and marnolite (Cordier), and the various rocks to which they have given rise. Thus, sandstones were changed into quartzites or quartzose mica-schist; clay into chiastolite-slate; magnesian clays into talcous, serpentinous, or chloritic schists; and marl into pyroxene, garnet, or epidote-rock. Argilite and marnolite have given rise to various rocks, according to the original character of the deposit or the degree of the subsequent changes, beginning with slate, and finally terminating in mica-schist and gneiss. Amongst these rocks he includes a number in which crystals of felspar have been developed, and classes them with the beds in Wales described as "trappean ash" by the Geological Surveyors of Great Britain. To gneiss is ascribed a double origin, being in some cases "incontestably stratified," and in others "a well-characterized eruptive rock." It is thus a connecting link between these two great classes of rocks, is "most intimately connected with granite, and its origin is evidently the same.... In reality it is only a variety of veined granite the crystallization of which appears to have been impeded. We are thus naturally led to admit that granite itself is a metamorphic rock. The same conclusion applies to the other plutonic rocks" (pp. 76, 86). The occurrence of graphite in various schists and even in granite itself is ascribed to organic bodies enclosed in the rocks previous to metamorphism. M. Delesse, however, in the concluding division of his essay clearly admits that some granites have been erupted. If, says he, "metamorphism be very energetic, it gives rise at once to both metamorphic and plutonic rocks. These latter, which appear to enjoy a greater amount of plasticity, have very often behaved as erupted rocks. They have been brought up again to the surface of the ground by internal pressures, and have filled the fissures and crevices of the crust of the globe in a state of veins or larger masses. But they are then no longer in contact with the corresponding metamorphic rocks, nor with those at the expense of which they were formed; this, moreover, is the most habitual manner of occurrence" (p. 88). The author then proceeds to point out that the plutonic rocks are often far too small to account for the magnitude of the metamorphic actions, and that even quartzite, mica-schist, and gneiss have sometimes been formed when no plutonic rock is present. He therefore concludes that plutonic rocks are the *effect*, and not the *cause*, of general metamorphism; and adopting this supposition, concludes by pointing out how it will serve to explain the variation in the character of granite at a greater or less distance from its extreme boundary.

[H. C. S.]

Geological Underground Map *of* Paris, *&c.* By M. A. Delesse, For. Mem. G. S., &c.

[Carte géologique souterraine de la Ville de Paris, publiée d'après les ordres de M. le Baron G. E. Hausmann, Sénateur, Préfet de la Seine, conformément à la délibération du Conseil Municipale du 8 Novembre 1857, et exécutée par M. Delesse, Ingénieur des Mines, Inspecteur des Carrières du Département de la Seine, 1858. Dessinée par Al. Babinski. Exécutée en chromolith. (Lemercier) sous la direction d'Avril f^{es}, Rue des Bernardins 18. En vente chez F. Savy, 20, Rue Bonaparte, Paris.]

This is a geological map of Paris (lithographed and printed in colours), on the scale of 15 millimetres to 100 metres; and it also indicates, by means of contour-lines of certain colours, the surfaces of the several formations beneath Paris, to the greatest depth reached by borings.

It is accompanied by three sections:—one across Paris from E. to W., from the Barrière de Vincennes to the Barrière de Neuilly: the other two are N. and S.,—one on the eastern side, from the Barrière d'Aunay to the Barrière de Charenton; the other on the west, from the Barrière du Roule to the Barrière de la Mothe Piquet. The vertical scale is 45 millimetres to 100 metres, being three times the horizontal scale.

The made ground ("remblais," r') and the drift ("terrain de transport," d') being supposed to have been removed, the following formations ("terrains") are seen on the map:—gypseous marls and gypsum (g'), lacustrine limestone (l'), middle sands ("sables moyens," s'), marls above the calcaire grossier (m'), calcaire grossier (p'), plastic clay (a'), and the cretaceous strata as far as the gault (c'). This map differs from ordinary geological maps in that it indicates the surfaces of these terrains. If, says the author of the map, we were to raise one after the other the terrains composing the subsoils of Paris, commencing with the latest, we should disclose successively so much of the surfaces as corresponds with each of these formations. To determine with precision these surfaces, we have chosen a particular bed to serve as a datum: it was necessary that this special bed should present well-marked mineralogical characters, easily recognizable in a boring; and it is generally that one which forms the upper surface of each terrain. For r' it is the lower surface of the made ground (r); for d', the lower surface of the drift (d); for g', the bed of gypsum (g); for l', the first bed of magnesian laminated clay below the marine beds (l); gl indicates the beds of gypsum in the lacustrine limestone; for s' is chosen the first bed of greenish-grey sand, gs being beds of gypsum in the sables moyens; for m', the first bed of the marls (m), gm being gypsum beds in the marls; for p', the bed of rock, or, that failing, the first bed of calcaire grossier (p); for a', the first bed of clay (" glaise ") and the calcareous marls (a); for c' the upper chalk or pisolitic limestone (c): from g to c inclusive, the datum bed is the upper stratum of the terrain. The calcaire grossier becoming marly in the northern part of Paris, is not represented with so much exactitude as the other terrains; nevertheless its surface is indicated on the sections by dotted lines.

Each of the special beds has had its bearings tested by accurate levellings and measurements made at certain points: hence all its inequalities of surface can be represented on the map by horizontal curves, of the same colour as that used to indicate the terrain to which the bed belongs, but of a darker tint; they are 10 metres apart. The horizontal curves of the drift represent the surface which would be obtained on removing this formation; they are 5 metres apart.

When a point has been determined by levelling, it is indicated on the map by a red dot, by the side of which are inscribed letters and figures (of colours corresponding to the terrains found beneath) which show the depth at which each special bed has been reached there. The gypsum beds have their thicknesses shown; but they are too irregular to be defined by horizontal curves.

The figures given as measurements in the map and sections are calculated from a datum-line 100 metres below the mean sea-level.

By the aid of this map and the great mass of exact information which it clearly gives as to the relative position and thickness of the several strata, any one may calculate approximately the depth at which each formation may be reached at any spot in Paris.

The level of the water, both subterranean and that of the river, is shown in the sections by a blue line and figures. It has been determined by the drainage-works carried on in August 1857.

The numerous underground works carried on in Paris, during the last few years especially, have all been turned to account in gaining as exact a knowledge as possible of the nature of the substrata. For the greater depths the author has had recourse principally to the borings executed by MM. Mulot and Degousée. The plan of Paris on which the map is based was published in 1856 by the Engineers of Bridges and Roads of the Municipal Service. [T. R. J.]

Hydrological Map *of* Paris, *&c.* By M. A. Delesse, For. Mem. Geol. Soc. &c.

[Carte hydrologique de la Ville de Paris, &c. &c. Par M. Delesse, &c., 1858.]

This is a chromolithographed map of Paris, of the same size and form as the foregoing (p. 20); it is accompanied by the same sections, and exhibits both the hydrographical and geological features of the area. This map, to the execution of which the author* has devoted nearly eight years, is constructed on novel principles. First, it gives the relief of the ground by horizontal curves; consequently it indicates how the water runs on the surface. Further, it shows the sheets of subterranean waters beneath Paris. Their contours and their flow are represented by horizontal curves a metre apart. These curved lines have been traced according to the measurement of the level of the water in a great number of wells; and therefore are not hypothetical. Indications are also given of the quality of the waters in Paris; and in this the author has had recourse to a plan used in England—namely, finding the quantity of soap used up in a given quantity of the water experimented upon. The degree of "hardness" thus obtained is inscribed on the map at the points where the several samples of water have been taken. Lastly, this map is a geological map of Paris; for it shows the formations which are bathed by the sheets of water. If, for instance, we take the sheet of infiltration water falling into the Seine, its upper surface bathes different formations, which are indicated on the map by corresponding colours. "It was interesting," says the author, "thus to trace the formations at the level of the subterranean water-sheet, as one sees how it traverses the several formations, and how the chemical compo- of the former depends on that of the latter."

This map has been executed by order of M. Hausmann, Prefect of the Seine, who has also charged the author with the construction of another similar map, which is to comprehend the whole of the Paris basin. These researches are connected with the undertaking known as the Somme-Soude Project, which contemplates the supply of good water on a large scale, by bringing the rivers of Champagne to Paris.

M. Delesse considers that this plan of hydrological mapping might be advantageously applied to mining districts where the works are much interfered with by water: the right places for adits, galleries, &c., would thus be easily fixed upon.

[T. R. J.]

Geological Map *of the* Southern Portion *of the* Ural Mountains. Constructed in 1854 and 1855, by Capt. Meglitzky and Capt. Antipoff, Engineers of the Corps des Mines.

This is a Russian map, on the scale of 1 inch to 8 miles (English), and is accompanied with several sections. Of these, three are parallel

* A letter from the author to Sir R. I. Murchison, V.P.G.S., has supplied much information respecting this map.—Edit.

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On a Jurassic Deposit *containing* Freshwater Fish *and* Insects *in* Eastern Siberia. By M. Ed. d'Eichwald.

[Sur un terrain jurassique à poissons et insectes d'eau douce de la Sibérie orientale. Par M. Ed. d'Eichwald. Bull. Soc. Géol. de France, 2e série, vol. xxi. 1863, pp. 19–25.]

M. d'Eichwald refers to his observations, made in 1846, in his 'Géognosie de la Russie,' on freshwater strata in the district of Nertchinsk, in Eastern Siberia, containing fossil Fish, described by him as *Pholidophorus macrorhynchus,* associated with *Posidonomya* and some larvæ of Insects.

In 1850* Dr. J. Müller proposed for this fish the name of *Lycoptera Middendorfii,* regarding the shale in which it was found as of Eocene age; while, on the other hand, M. d'Eichwald had considered the strata as belonging to some member of the Jurassic system†.

A portion of this paper consists of notes upon the fossils occurring in these beds. The Fish already mentioned he states to agree pretty well generically with *Pholidophorus,* but better with *Æthalion* of Münster (1842), which Prof. Agassiz somewhat later classed as a subgenus of *Pholidophorus.*

The remains of Neuropterous Insects accompanying the Fish the author named *Ephemeropsis trisetalis*; with these occur *Estheria Middendorfii,* Jones, *Paludina pura,* D'Eichwald, and a small species of *Cyclas.* He next remarks, that up to the present time the relative age of the shale has not been satisfactorily determined. It readily splits into very thin layers, between which are found, in great numbers, *Æthalion* (*Pholidophorus*) *macrorhynchus* and *Estheria,* whilst *Ephemeropsis, Paludina,* and *Cyclas* are sparingly met with. The shale is found to pass into an argillaceous schist, a rock which constitutes everywhere in Eastern Siberia the highest mountains. It is doubtful, however, whether this is the same schist which contains fossil Fish upon the banks of the River Tourga, and is probably of older date; it is generally devoid of fossils, but forms allied to some Liassic species of *Monotis,* that occur in the Tyrol, are sometimes met with.

The schist occupies the eastern shore of the Gulf of Oxhotzk, and contains *Monotis Ochotica,* Keys., with its several varieties, which were named by Keyserling *M. minor, M. media,* and *M. major* respectively. It may therefore be regarded as a passage-bed to the

* Middendorf, 'Voyage en Sibérie,' p. 261.

† See also Quart. Journ. Geol. Soc. vol. xix. pp. 71 *et seq.*

Lias of the Tyrol, which as a marine sediment may be contemporaneous with the Jurassic strata of the Tourga, which were deposited in a freshwater lake of very considerable extent.

He further adds his belief that Jurassic limestone is clearly developed in Northern Siberia and in the Islands of the Arctic Ocean, as previously noticed by him, in 1841, in his memoir upon the *Ceratites* of the Muschelkalk of Eastern Siberia. [R. T.]

On the Geology *of* Albania. By Dr. A. Boué.

[Proceed. Imp. Acad. Vienna, January 21, 1864.]

Before the year 1859, the Albanian River Drin flowed to the Adriatic through the valley of Zadrima and the limestone-cliffs of the defiles of Baldrin and Lesch. In 1859 an inundation of this river, probably simultaneous with another of the River Kiri, caused the Drin to work out from its north-west source in the Skela Mountains a new course through cultivated lands, down to its junction with the Kiri, which falls into the Boyana. The Rivers Devol and Scumley, in Middle Albania, separated only by a large plain, without any mountains or hills, likewise unite during periods of inundation, at least at the narrower part of this isthmus. Westward, a small hilly portion remains, like an isle between the sea and the two rivers. Between the basin of Scutari and the Gulf of Arta, and still more to the south, a broad band of land is exclusively occupied by Tertiary deposits overlying an old depressed formation of Secondary limestones, which appear through the Tertiaries only in some few places. Eocene strata are prevalent in Epirus ; Miocene and Neogene in Northern and Central Albania. A fine section of these deposits is to be met with on the southern slope of the Graba-Balkan. On this slope, the Nummulitic Limestone is overlain by a thick deposit of blue argillaceous marls. Above this, strata with *Cerithia* and *Neritinæ*, such as are not met with in the Vienna Basin, are to be seen. The uppermost deposit is a thick layer of quartzose Leitha-conglomerate (Neogene). As in Istria, only on a larger scale, the Eocene deposits in South Albania comprise two great subdivisions ; the Nummulitic limestone forms the high ground, and the marls and sandstones occupy the depressions and erosions, both being overlain, in some of the larger valleys, by freshwater limestones and alluvium. Several sulphurous hot springs are known to exist in North Albania, and it may be worth notice that there, as at Baden, near Vienna, gypsum occurs imbedded in Secondary limestone. [Count M.]

On the Coal-deposits *of* Gross-Raming (Upper Austria). By Baron Sternbach.

[Proceed. Imp. Geol. Instit. Vienna, February 16, 1864.]

Five seams of this Coal, of which only the third, about 3 feet thick is profitably worked, are imbedded in alternately compact and friable shales, interstratified with grey micaceous sandstones of Lower Liassic age. The shales forming the floor of the second seam include ferruginous marls with vegetable impressions, among which *Camptopteris Wilsoni* prevails, while in the shales of the roof *Pecopteris Whitbyensis* is the predominant form, though specimens of *Tæniopteris vittata* have also been met with. Some layers of the imbedding rock are full of organic remains; for instance, *Pleuromya unionides, Pecten infra-liassicus, Goniomya rhombifera, Panopæa liassica,* &c. The mining-operations, after having been carried through barren rocks and several unprofitable Coal-seams, at last led to the opening of a coal-seam 9 feet thick, of which from 5 to 6 feet are good laminated coal, giving 60 per cent. of coke and only 20 per cent. of ash. At several places the workings reached as far down as the variegated Liassic marls. [COUNT M.]

On the NEOGENE DEPOSITS *of the* VALLEYS *of the* MÜRZ *and* MUR (STYRIA). By Herr D. STUR.

[Proceed. Imp. Geol. Instit. Jan. 19, 1864.]

Two horizons differing in age may be distinguished in these deposits, the upper portion of the more ancient consisting of conglomerates, with hollow pebbles, and sandstones; and the lower part of shales, with sometimes considerable coal-seams; both subdivisions contain remains of *Mastodon angustidens, Dinotherium Bavaricum,* and other Mammals. This older series may be equivalent to the marine strata of the Vienna basin. It is overlain by plastic clay, with occasionally very considerable coal-seams, both containing intercalated beds made up in places almost entirely of *Congeria triangularis,* Partsch; they are certainly equivalent to the uppermost freshwater strata of the Vienna Basin, and are succeeded by an extensive gravel-deposit. [COUNT M.]

On BIVALVES *from* GOSAU. By Dr. ZITTEL.

[Proceed. Imp. Acad. Vienna, December 10, 1863.]

THE Gasteropods of this highly interesting deposit have been described by Dr. Zékély (Jahrb. k.-k. geol. Reichsanst. 1852). Subsequently Prof. Reuss published descriptions of the Corals and Foraminifera, Chev. von Hauer those of the Cephalopods, and Dr. Stoliczka those of some freshwater Gasteropods from the same locality. Dr. Zittel, of the Imperial Museum of Vienna, has lately published descriptions and figures of seventy-three species of Gosau Dimyarian Bivalves, all of which belong to known genera, stated (with the exception of *Cyclina*) to occur in Cretaceous deposits. The greater number of the species are new, and only a few have been hitherto met with in other localities. Of the 73 species, only 17 have been found (most of them in Southern France) beyond the Austrian Alpine regions; all the others (6 of which had been previously described by Sowerby and other authors) are confined to the Gosau strata, in the strict sense of the term. The species of *Unio*, *Cyclas*, and *Cyrena* which Dr. Stoliczka found, associated with Gasteropods, between the coal-seams of the Wand, near Wiener-Neustadt (S. of Vienna), are of particular interest as members of an ancient freshwater fauna, the former existence of which has been recently confirmed by the discovery of gigantic Saurian remains. [COUNT M.]

On some GEOLOGICAL SECTIONS *in the* TRAISENTHAL (LOWER AUSTRIA). By M. LIPOLD.

[Proceed. Imp. Geol. Instit. Vienna, March 15, 1864.]

THESE sections exhibit the following succession of strata, in ascending order:—(1.) Werfen beds, with *Myacites Fassaënsis* and other characteristic organic remains. (2.) Rauchwackes. (3.) Dolomite, dark-coloured and partly bituminous. (4.) Guttenstein beds, black spathose limestones, with *Ceratites Cassianus*. (5.) Nodular black or light-grey limestones, containing nodules of chert, alternating with black, thinly schistose limestones, including *Ammonites Aon* and *Halobia Lommeli*—the Gossling beds. (6.) Sandstones and shales with intercalated coal-seams; shales with impressions of vegetables, as *Pterophyllum longifolium*, *Equisetites columnaris*, *Pecopteris Stuttgartensis*, &c., and overlain by slates with *Posidonomya Wengensis*, and a thin bed of limestone with *Ammonites floridus*—Lunz strata. (7.) Black or brownish, partly dolomitic, limestones, in thin layers, with *Pecten filosus*, *Corbis Mellingi*, *Perna Bouei?*, *Myoconcha*, &c., and above them similar light-coloured limestones with *Myophoria Whatleyæ*, *Cardita crenata*, &c., overlain by dolomites—Opponitz strata. (8.) Kössen beds, overlain by (9.) Hierlatz strata near Silienfield, and by Liassic variegated marls with *Ammonites* near Traisen. (10.) Red Jurassic limestones (Klausen beds) with *Ammonites triplicatus*. (11.) Upper Jurassic Aptychus-slates and limestones. (12.) Neocomian strata.

The Lower (Alpine) Trias is represented by the deposits Nos. 1 to 4, the Upper (Alpine) Trias by Nos. 5 to 7, the Alpine Lias by Nos. 8 & 9. The whole of the Coal-deposits in the lower part of the North-east Calcareous Alps are interstratified with the Upper Trias, while those on the southern margin of the Vienna-sandstone zone are subordinate to the Gresten (Middle Lias) beds. [COUNT M.]

E. and W. sections across the country, with the heights determined by the barometer, and on the scale of 1 inch to 16 miles horizontally; and fourteen are smaller uncoloured local sections.

The following formations are indicated by colours on the map and long sections:—A. Silurian. Green and grey sandstone and conglomerate; green, grey, and other argillaceous schists and quartzite. (*Obolus Apollinis, Lingula oblonga, Orthis calligramma, O. testudinaria.*) B. Devonian. Limestone, grey and white; calcareous sandstone (Brook Pismianka), and schists. (*Terebratula elongata, T. Arimaspus, T. aptycha, T. Pugnus, T. cuboides, Spirifer Tenticulum, Sp. muralis, Sp. Archiaci, Orthis resupinata, Avicula reticulata, Pentamerus galeatus, &c.*) C. Carboniferous. Grey clay and schist (*Pecopteris, Cyclopteris, Voltzia, Sphenopteris, Nœggerathia, &c.*). Ferruginous Sandstone. Yellow, grey, and black limestones, argillaceous schist, and grey and yellow sandstone (*Goniatites, Fusulina cylindrica, Spirifer Mosquensis, Sp. striatus, Productus antiquatus, P. punctatus, P. giganteus, Cyathophyllum, &c.*). D. Permian. Red sandstone, conglomerates, clays, and limestones. E. Cretaceous. White and yellow clays, sandstones, and conglomerates (*Belemnitella mucronata, Terebratula carnea, T. elongata, Rhynchonella octoplicata, Ostrea vesicularis, &c.*). F. Alluvial clay and sand. G. Igneous rocks: *a*, granite, granito-syenite; *b*, diorite and porphyry (greenstone and felspar-porphyry); *c*, serpentine; *d*, quartz-veins. H. Metamorphic rocks: 1. mica-, talc-, and chlorite-schists; 2. conglomeratic schist and jasper.

The auriferous sands are also marked (by a yellow line), and the numerous points where astronomical and barometrical observations were made are also indicated. The barometrical stations are used to indicate the lines of section; on the latter the heights are given in English feet.

The smaller sections are:—Fig. 1. Curved strata of Silurian sandstone and argillaceous schists on the banks of the Brook Maloi Suriane. Fig. 2. The Turate Mountain, showing Silurian sandstone, limestone, and schist, and conglomeratic schist. Fig. 3. The Silurian sandstone and clay-schist on the River Arantache. Fig. 4. The Silurian beds (sandstone and clay-schist, with breccia and jasper) on the banks of the Brook Gusicha. Fig. 5. Section at the village of Verchneosernoy, to the east, showing the beds of the Carboniferous Limestone, alternating with sandstones and conglomerate.

Fig. 6. Section at the village of Griasnuschinskoy, showing the strata of Carboniferous Limestone (*a–c*), the Silurian rocks (alternations of green and grey sandstone, clay-schists, and conglomerate), and dykes of diorite (*g*). Fig. 7. Strata of the Carboniferous Limestone at the Factory of Kananicolsky, to the west (*a*, sandstone; *b*, grey and black limestone; *c*, Fusulina-limestone; *d*, Encrinital limestone; *e*, calcareous sandstone; *f*, limestone with *Productus antiquatus, P. punctatus, Spirifer Mosquensis, &c.*; *g*, limestone with *Cyathophyllum, &c.*; *h*, argillaceous and pebbly schists; and *i*, Silurian rocks). Fig. 8 shows a complete section of the Carboniferous, Silurian, and Metamorphic rocks at the Factory of Preobra-

gensky, to the west:—*a*, sandstone; *b*, grey and black limestone; *c*, Fusulina-limestone; *d*, Encrinital limestone; *e*, sandstone; *f*, limestone with *Productus striatus*, *Spirifer Mosquensis*, *&c.*; *g*, limestone with *Cyathophyllum*, *&c.*; *h*, argillaceous and conglomeratic schists; *i*, Silurian sandstone and schist; *k*, conglomerate; *l*, talc-schists; *m*, mica-schists; *n*, serpentine-dyke; *p*, conglomeratic schists (locally overlying the mica-schist); *q*, quartz-veins. Fig. 9. Carboniferous strata on the banks of the River Maloi Urtasime:—*a*, grey and black limestone; *b*, yellow limestone, with Encrinital limestone (*c*); *d*, conglomerate; *e* & *f*, alternating clay-schist and sandstone; *g*, limestone with *Cyathophyllum*, *&c.* Fig. 10. Carboniferous Limestone on the porphyries on the banks of the River Verchniaia Orlofka:—*a*, porphyry; *b* & *c*, strata of Carboniferous Limestone, with abundant fossils, and not at all metamorphosed; *d*, dykes of diorite in the porphyry. Fig. 11. Carboniferous Limestone on the Brook Maloi Suriane. Fig. 12. Contorted strata of Carboniferous Limestone near the village of Kugartschi.

Fig. 13. Cretaceous strata:—*a*, white and yellow clay with seams of sand (*Belemnitella mucronata*, *Terebratula carnea*, *T. elongata*, *Rhynchonella octoplicata*, *Ostrea vesicularis*, *&c.*); *b*, sandstone and conglomerate with chlorite. Fig. 14 is a section of the Michailavsky bed of gold-bearing sand on the banks of the Brook Suvunduc:—*a*, grey Carboniferous Limestone; *b* & *c*, alternating argillaceous schist and sandstone below the limestone; *e*, quartz-vein through the limestone; *d*, superficial auriferous sand.

[T. R. J.]

On the MOLASSE *of* SOUTHERN BAVARIA. By FRANZ R. VON HAUER.

[Proceed. Imp. Acad. Vienna, January 3, 1861.]

AFTER a close examination of the Prien Valley, which opens into the Chiem-See, Prof. Emrich admits five subdivisions of the South Bavarian Molasse. The lowest is of marine origin, and palæontologically parallel to the strata of Alzey on the Rhine. This is immediately overlain by the lignitiferous freshwater or brackish strata of Miesbach. The third or middle subdivision (Conchiferous Molasse), of marine origin, with organic remains identical with those of the Swiss marine Molasse, is overlain by strata containing fossil forms characteristic of the marine deposits of the Vienna basin. The fifth or uppermost subdivision is characterized by the presence of freshwater Univalves, *Melanopsides* and *Neritinæ*. [COUNT M.]

On the DEVONIAN *and* CARBONIFEROUS ROCKS *of* MORAVIA. By MM. WOLF and LIPOLD.

[Proceed Imp. Geol. Instit. Vienna, February 26, 1861.]

MESSRS. WOLF and LIPOLD, at the request of the "Wernerian Society" of Brünn, surveyed in the autumn of 1860 the environs of

Olmütz, Eastern Moravia. Crystalline rocks (granite, mica-schist, argillaceous slates, syenite, phyllites, and varieties of quartzite), overlain by extensive palæozoic deposits, are prevalent in the space comprised between Brünn, Boskowitz, and Olmütz. Semicrystalline limestones, including beds of brown iron-ore (Baron Reichenbach's "Lathon") are intercalated between the uppermost crystalline and the older palæozoic rocks. The nature and subdivisions of these last rocks have been lately better cleared up by the discovery of some fossiliferous localities. The oldest palæozoic strata are overlain by a zone of limestones, $\frac{1}{2}$ to $\frac{3}{4}$ of an Austrian mile in breadth, in fantastically shaped groups, probably the remains of a once continuous mountain-range. The presence of *Stringocephalus Burtini*, a characteristic Lower Devonian form, allows this limestone to be parallelized with those of the Eifel in the Rhenish System. A narrow zone of red-and-green-spotted marbles may represent the Clymenian Limestone of the Upper Devonian series.

Over these lower strata a complex series of alternating slates and sandstones, comprised hitherto under the general denomination of "Greywacke," form an extensive plateau, separated northward from the higher subdivisions by a considerable depression, and sloping eastward by degrees towards the Miocene and Diluvial deposits. Some of these slates are worked on an extensive scale between Olmütz and Troppau.

Palæontological investigations have now ascertained that this whole group, hitherto known as Greywacke, belongs in reality to the lowermost portion of the Carboniferous series, and is analogous to the so-called "Kulm Strata." Prof. Göppert had already inferred, from the vegetable remains found in it (especially from *Calamites transitionis*), its analogy with the "transition" deposits of Haynichen (Saxony) and with the Posidonomya-slates of Nassau,—a view subsequently confirmed by the discovery of other vegetable remains and of *Goniatites Crenistria*, and recently fully established by the discovery of a most characteristic fossil form, the *Posidonomya Becheri*.

Limestones of the Upper Jurassic series occur near Brünn and Blansko. [Count M.]

On the Mountains *South of* Kronstadt, Transylvania.

By Franz Ritter von Hauer.

[Proceed. Imp. Geol. Instit. Vienna, February 26, 1861.]

The orographical features of this group are quite different from those of the neighbouring mountains of Fogaras. Instead of a uniform longitudinal range, they offer the aspect of colossal massifs, sometimes with extensive plateaux, isolated from each other by deep valleys, running irregularly in every direction, and sloping towards the plains and the lower mountain-region at uncommonly steep angles, so as to form precipices several thousand feet deep. The altitude of these massifs varies generally between 4100 feet and 5700 feet; the two highest among them rise, one to 7050 feet, and the other to 7900 feet.

A white limestone, probably Jurassic, forming cliffs of grotesque configuration, and joining north-westwardly the crystalline slates of the Fogaras Mountains, is the prevailing rock in this mountain-group. Organic remains lately found by Mr. Stur (among them *Rhynchonella plicatella*, Sow., and *Terebratula sphæroidalis*, Sow.) are indicative also of the presence of the Brown Jura, a subdivision the existence of which in Transylvania was hitherto unknown. Next to the White Jura in extent and importance, come conglomerates of primary rocks, and sometimes enormous boulders of the white limestones occurring in some isolated localities around Kronstadt. These conglomerates remind us, by their prevalent greenish tints, of the greenish Eocene sandstones of the Alps, and are so connected with the other undoubtedly Eocene conglomerates around Kronstadt that they must be consequently ascribed to the same early Tertiary period.

A sandstone, seeming to dip beneath the before-mentioned Jurassic strata, includes organic remains belonging, as far as they are as yet recognized, to the Upper Cretaceous fauna. Forms characteristic of the Lower Cretaceous (Neocomian) strata, as *Belemnites dilatatus*, De B., and a large tooth of *Sphærodus* (probably *Sphær. Neocomiensis*, Ag.) have been found among the organic remains of Vallye Drakuluj near Kronstadt.

[Count M.]

On the Large Tertiary Carnivora *of* Austria. By Prof. E. Suess.

[Proceed. Imp. Acad. Vienna, March 7, 1861.]

The Tertiary and Post-tertiary deposits, so important on account of their organic remains in throwing light on the question, how far the repeated changes undergone by organic creation are the effects of changes in the external condition of life, have been during a number of years an object of sedulous investigation to the palæontologists of Vienna, and especially to Prof. Suess, who, at the expense of the Imperial Museum, explored in 1860 the western borders of the Vienna basin, and caused the ossiferous deposits of the Baltavar, near Eisenburg (W. Hungary), to be thoroughly searched on an extensive scale. This locality, first discovered by M. von Schwaberau, corresponds in its general features with the well-known deposit of Pikermi, near Athens, comprising remains of *Machairodus*, *Hyæna*, *Antilope*, a gigantic species of Giraffe, and many other genera. The determination of the Baltavar fossils has been effectually assisted by a rich collection of Pikermi fossils lately presented to the Imperial Museum by Count Breuner-Felsach, formerly Austrian Envoy at the Court of Greece. Prof. Suess in his paper describes three species, *Machairodus* (a genus analogous to the Lion of the present period), *Hyæna eximia*, and *Amphicyon intermedius*—an animal similar to the Wolf, only larger in size.

[Count M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the Stratigraphical Succession *of the* Beds *in the* Savoy Alps. By M. Ch. Lory.

[Note sur la constitution stratigraphique de la Haute-Maurienne, par M. Ch. Lory. Bulletin de la Société Géologique de France, deuxième série, vol. xviii. p. 34.]

The subject referred to in an abstract contained in the 'Quarterly Journal,' vol. xvii. part 2. (Miscell.) p. 16, has received further elucidation in the communication of M. Lory, who confirms the deductions of M. Favre, and considers that the discovery of the Nummulitic strata underlying the Lias proves the reality of the great overthrow which has reversed and replicated the strata in a manner astonishing even to those best acquainted with similar minor phenomena elsewhere. M. Lory has given general sections of the structure of the Alps; and M. Favre adds a letter and section giving full details of the striking instance of reversal on a grand scale shown in the district of St. Jean de Maurienne, which will henceforward become a typical instance.

[S. R. P.]

On the Palæozoic Rocks *of* Belgium *and the* North *of* France. By M. Jules Gosselet.

[Mémoires sur les terrains primaires de la Belgique, des environs d'Avesnes et du Boulonnais, par Jules Gosselet: Paris, 1860. Also "Observations," &c., Bulletin de la Société Géologique de France, deuxième série, vol. xviii. p. 18.]

M. Gosselet has now occupied several years in the careful field-work and study, the results of which are embodied in his Memoir of 1860. In the subsequent communication to the Society, he gives a *résumé* of the work. A short abstract of both will justify us in welcoming this valuable addition to palæozoic literature, especially in regard to that portion of it which affects the relationship of the uppermost Devonian beds to the Lower Carboniferous system. After referring to the history of the inquiry and paying a just tribute to the excellency of the geological topography of Dumont, he states that he has ascertained both stratigraphically and palæontologically the existence of eleven principal divisions, which have a general correspondence with the divisions of Dumont. These are (reversing his order for the sake of naturalness, though not altering the enumeration)—

1.	Coal-grits and shales		Carboniferous.
2.	Upper Carboniferous Limestone (Visé)		
3.	Lower Carboniferous Limestone (Tournay)		
4.	Psammites of Condros	Upper	Devonian.
5.	Slates of Famenne		
6.	Givet limestone	Middle	
7.	Calceola-slates	Lower	
8.	Burnot conglomerate		
9.	Grauwacke with *Leptæna Murchisoni*		
10.	Conglomerates and roofing-slates		
11.	Slates and quartzites, with porphyry		Silurian.

No. 1. The productive coal-measures offer nothing worthy of remark save the author's conclusions in favour of the opinion that the coal-basin of the Boulonnais is the prolongation of that of Mons, and is not a bed in the Lower Carboniferous series. His reasons will be found in the Memoir, p. 132.

No. 2. M. Gosselet considers that there is sufficient palæontological evidence for the division (first suggested by M. de Koninck) of the great mass of limestones and shales below the coal into two groups, typified by the limestones of Visé and Tournay. He thus characterizes the former in Belgium:—

Alum-shales and limestones with *Productus carbonarius* and *Goniatites diadema.*

Limestones with *Productus undatus.*

Productus-limestone. *Productus giganteus, P. sublævis,* and *P. cora.*

Dolomites.

No. 3. Lower Carboniferous Limestone. Tournay.

Nodular or cherty limestone.

Crystalline limestone. *Spirifer mosquensis* and *Sp. semireticulatus.*

Black limestone with *Productus Heberti.*

No. 4. Condros psammite.—Between the Carboniferous Limestone and that of Givet there occurs a great series of coarse slates, grits, and sandstones, which M. d'Omalius d'Halloy designated by this name. Dumont separated from them the schists of Famenne; and, though he afterwards abandoned the division, M. Gosselet considers it established. There are several stages of No. 4; but the uppermost Devonian rocks, the Cypridina- and Clymenia-slates, appear to be everywhere absent. The upper beds at Oetrungt are characterized by *Phacops latifrons, Terebratula concentrica, T. hastata, T. Bolonensis, Spirifer Verneuilii, Orthis crenistria, O. arachnoidea,* and *Productus scabriculus.* The whole group, wherever lime is present, is abundantly rich in fossils, amongst which *Sp. Verneuilii* plays the most considerable part.

No. 5. The schists of Famenne are the same as are designated in the communication to the Society the *Terebratula cuboides* beds.

They are well displayed around and within Fort Condé, near Givet, as follows :—

Greenish schists with *Spirifer Verneuilii.*
Black schists with *Cardium palmatum.*
Schists with limestone-nodules and *Terebratula cuboides.*
Blue limestone.
Schists with *Receptaculites* and *Terebratula æquiconvexa.*

No. 6. The great Givet limestone is identical with that of Paffrath. Its characteristic fossils are *Macrocheilus arcuatus, Euomphalus rotula, Rotella heliciformis, Murchisonia coronata,* and *Stringocephalus Burtini.* Different stages are characterized by different Spirifers. At Mâcon (near Chimay) and in the Eifel, *Phacops latifrons, Orthoceras nodulosum, Gomphoceras inflatum, Lucina proavia,* and *Pentamerus formosus* occur.

No. 7. This is a series of argillaceous schists with intercalated limestones characterized by *Calceola sandalina, Spirifer speciosus, Pentamerus galeatus,* and *Terebratula primipilaris.* In other places *Chonetes minuta, Spirifer cultrijugatus,* and *Leptæna depressa* occur in different beds of this series.

No. 8. This is a great development of red conglomerate and sandy grits, comprising paving-stone beds barren of fossils; but M. Hébert reports having found at one place within its area *Dolabra Hardingii, Avicula fasciculata, Productus Murchisonianus,* and a *Spirifer* like *Sp. Bouchardii.*

No. 9. This is the "Coblentzien" of Dumont. The coarse rock to which the well-known and little-liked term of "grauwacke" is attached contains *Pleurodictyum problematicum, Leptæna Murchisoni,* and some *Terebratulæ.*

No. 10. Lastly, the Devonians terminate downwards in a great series of rocks, principally conglomerate, called by Dumont "gédinien," and separated stratigraphically and mineralogically into five divisions, one of which is fossiliferous and contains *Dalmanites, Homalonotus, Grammysia,* two small *Spiriferi, Chonetes sarcinulata,* two species of *Orthis, Cœlaster constellatus,* and *Tentaculites ornatus.*

No. 11. This is the "Ardennais" of Dumont (comprising three large divisions well characterized mineralogically), which, though at present barren as to fossils, is usually agreed to be Silurian from its position.

The Memoir contains the author's views as to the correlation of these groups with the Palæozoics of other countries, copious lists of fossils, and is well illustrated by sections.

It is quite evident that the Lower Devonian rocks are so well characterized in Belgium that we may obtain from them considerable light on our own more fragmentary and disturbed deposits. By identifying one band of the Plymouth limestone with that of Givet, we may obtain a useful horizon for the middle of the great marine group constituting the western extremity of our own island.

[S. R. P.]

On the Accumulation *of* Detritus *in the* Steinfeld.
By Lieut.-Col. Jonklar.

[Proceed. Imp. Acad. Vienna, March 14, 1861.]

The plain called "Steinfeld" near Wiener-Neustadt (S. of Vienna) is in reality a flattened conoidal accumulation of detritus, the apex of which lies at Wöllersdorf at the mouth of the Piesting Valley, from whence it slopes away in every direction, the angle of inclination being least in the direction of Pottendorf. The maximum length (2 Austrian or about 10 English miles) is between this place and Wöllersdorf; the maximum breadth ($1\frac{1}{2}$ Austrian or about $7\frac{1}{2}$ English miles) is between Neustadt and Leobersdorf. There can be no doubt that the whole accumulation has come out of the Piesting Valley. A number of careful measurements make its volume to be 450,387,000 cubic fathoms (the fathom being equal to 216 cubic feet)—about $\frac{1}{20}$ of the cubic contents of the whole Piesting Valley, calculated to be 9033 millions of cubic fathoms. If the proportional densities of the detritus and of solid limestone are taken into consideration, the total mass of this accumulation of detritus may amount to the thirtieth part, in volume, of the quantity of solid limestone required to fill up completely the Piesting Valley in its present extent. [Count M.]

On the Hauyine-rock *of* Transylvania.
By K. Ritter von Hauer *and* Director W. Haidinger.

[Proceed. Imp. Geol. Instit. Vienna, May 28, 1861.]

Specimens of hauyine discovered by M. Herbich near Ditro (Transylvania), have been analysed in the laboratory of the Vienna Imperial Institute by K. Ritter von Hauer, who found them to contain a notable quantity of chlorine, a substance also stated to occur in sodalite. This circumstance, together with its granitoid crystallization, assigns to the Ditro mineral its place among the mineral species or varieties named Sodalite, Roselite, Ittnerite, Sapphinine, Spinellan, Hauyne, and Lapis Lazuli. Its colour is between azure and sky-blue; its specific gravity 3·318; its hardness according to Mohs' scale 5·5 (between fluor-spar and felspar). The rock for which Director Haidinger proposes the name of "Hauyne-Rock" is a granular aggregate of hauyne, orthoclase, cancrinite, elæolite, and oligoclase, interspersed with minute particles of black amphibole, mica, magnetic iron, sphene, calcareous spar, &c. The whole compound, when cut and polished, is conspicuous for its beautiful mixture of blue, white, grey, and reddish-yellow tints, which, together with its hardness, makes it, when polished, a very fit material for ornamental objects.

MM. Quaglio and Fritsch have begun the regular exploitation of this new and fine mineral substance, and intend to send specimens of it to the London Exhibition of 1862.

[Count M.]

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TO THE

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