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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
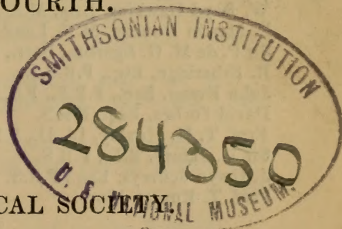—*Novum Organum, Præfatio.*

VOLUME THE TWENTY-FOURTH.

1868.

PART THE FIRST.
PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

List

OF THE

OFFICERS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

Elected February 21, 1868.

President.
Professor T. H. Huxley, LL.D., F.R.S.

Vice-Presidents.

Sir R. I. Murchison, Bart., K.C.B., F.R.S. | Earl of Selkirk, F.R.S.
Prof. A. C. Ramsay, LL.D., F.R.S. | Rev. T. Wiltshire, M.A., F.L.S.

Secretaries.

P. Martin Duncan, M.B. Lond., F.R.S. | John Evans, Esq., F.R.S., F.S.A.

Foreign Secretary.
Prof. D. T. Ansted, M.A., F.R.S.

Treasurer.
J. Gwyn Jeffreys, Esq., F.R.S.

COUNCIL.

Prof. D. T. Ansted, M.A., F.R.S.
Duke of Argyll, D.C.L., F.R.S.
W. Boyd Dawkins, Esq., M.A., F.R.S.
P. Martin Duncan, M.B. Lond., F.R.S.
Sir P. de M. G. Egerton, Bart., M.P., F.R.S.
R. Etheridge, Esq., F.R.S.E.
John Evans, Esq., F.R.S., F.S.A.
David Forbes, Esq., F.R.S.
Prof. T. H. Huxley, LL.D., F.R.S.
Sir H. James, R.E., F.R.S.
J. Gwyn Jeffreys, Esq., F.R.S. & L.S.
Prof. T. Rupert Jones.

Sir Charles Lyell, Bart., M.A., D.C.L., F.R.S.
Prof. John Morris.
Sir R. I. Murchison, Bart., K.C.B., F.R.S.
Robert W. Mylne, Esq., F.R.S.
Prof. A. C. Ramsay, LL.D., F.R.S.
Earl of Selkirk, F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Alfred Tylor, Esq., F.L.S.
Rev. Thomas Wiltshire, M.A., F.L.S. & A.S.
Searles V. Wood, jun., Esq.
Henry Woodward, Esq., F.Z.S.

Assistant-Secretary, Librarian, and Curator.
H. M. Jenkins, Esq.

Clerk.
Mr. W. W. Leighton.

Library and Museum Assistants.

W. Stephen Mitchell, LL.B., F.L.S. | Mr. Sydney B. J. Skertchly.

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PART I.—ORIGINAL COMMUNICATIONS.

LIST OF THE FOSSILS FIGURED AND DESCRIBED IN THIS VOLUME.

[In this list, those fossils the names of which are printed in Roman type have been previously described.]

EXPLANATION OF THE PLATES.

ERRATA ET CORRIGENDA.

Page lxv, line 5, *for* latter *read* last.
,,   8, line 20, *for* it *read* the chalk.
,,   32, line 36, *for* Palæontological *read* Palæontographical.
,,   37, line 5, *dele* total.
,,   49, woodcut, the rocks marked *b* should have been represented as *conformably* underlying the small synclinal in the middle of the section.
,,   61, line 29, *dele* the presence of.
,,   160, fig. 4, right-hand end of section, near base-line, *add* 1.
,,   ,,   fig. 5, left-hand end of section, near base-line, *add* 1.
,,   179, line 5 from bottom, foot-note, and elsewhere, *for* intræglacial *read* intraglacial.
,,   223, end of line 6, *add* have.
,,   287, description of woodcut, *add* F. Fault or slip.
,,   305, line 6 from bottom, *for* it flames ; shooting *read* it ; flames shooting.
,,   421, line 30, *for* north-west *read* north-east.
,,   437, line 15 from bottom, *for* N. 10° E. *read* E. 10° N.
,,   446, line 10 in table, and elsewhere, *for* Entomos *read* Entomis.
,,   454, line 27, *for* Painton *read* Paignton.
,,   466, line 4, *for* show *read* shows.
,,   474, woodcut, the chalk should have been represented conformable to the underlying Gault, and the high-inclination Palæozoic rocks should have been continued beneath the sea-level.
,,   475, line 11 from bottom, *after* Weald *insert* Clay.
,,   556, beginning of line 25, *insert* on.
,,   574, line 5, *after* Tertiary *add* Beds.

GEOLOGICAL SOCIETY OF LONDON.

REPORT OF THE COUNCIL.

THE Council of the Geological Society, in presenting their Annual Report to the Fellows, have more cause than usual to congratulate them on the increasing prosperity of the Society, although the monetary pressure of the last twelve months has produced a temporary diminution of the receipts.

During the year 1867 the number of the Society has been increased by the election of no less than 62 new Fellows; of these, 55 had paid their fees up to the end of the year, making with 5 previously elected, who paid their fees in 1867, a total increase of 60 new Fellows. On the other hand, the Society has sustained the loss of 22 Fellows by death and of 2 by resignation, making a net increase of 36 ordinary Fellows.

One Foreign Member has been elected in the place of one deceased, and one Foreign Correspondent has been elected in place of the one elected to fill the vacancy in the list of Foreign Members.

The total number of the Society at the close of 1866 was 1149; and at the close of 1867, 1185.

The expenditure of the past year has exceeded the income by the sum of £18 1s. 8d. This excess is less than might have been expected from the falling off in the receipts under the heads of Compositions and Annual Contributions; but as this falling off is merely the result of deferred payments, it is probable that the receipts of the current year will show a corresponding increase. The number of Contributing Fellows is now 469, and their annual payments should reach the sum of £900, whereas during the past year not quite three-fourths of that amount was collected under the head of Annual Contributions.

The Expenditure has been somewhat increased by the volume of the Quarterly Journal having been unusually bulky. The amount

to the credit of income for 1867 has also been diminished by the transfer from income to capital of the money advanced on account of the Bequest Fund in previous years.

The funded property of the Society has been increased by the investment of £300 in Consols, and now reaches the sum of £4860.

The Council have to announce the completion of Vol. XXIII. of the Quarterly Journal, including a Supplementary Number published in December, and the publication of the first part of Vol. XXIV.

They have also to announce the appointment of Mr. W. W. Leighton to the office of Clerk, rendered vacant by the resignation of Mr. R. Fenton; and of Mr. W. Stephen Mitchell and Mr. Sydney B. J. Skertchly as Museum and Library Assistants, in the room of Mr. R. Tate and Mr. Horace Woodward, who resigned their respective posts last September.

The Council have awarded the Wollaston Medal to Professor Carl F. Naumann of Leipzig, in recognition of his labours, extending over nearly half a century, in the departments of Geology, Mineralogy, and Crystallography, and especially for the admirable series of Geological Surveys of Saxony and adjoining countries, executed by himself and his coadjutors between the years 1836 and 1843, and for the great standard work on Geology ('Lehrbuch der Geognosie'), which, with the excellent courses of lectures delivered by him at Freiburg and at Leipzig, has exercised a powerful influence on the education of the newer generation of continental geologists.

The balance of the proceeds of the Wollaston Fund has been awarded to M. J. Bosquet, of Maestricht, in aid of the valuable researches on the Tertiary and Cretaceous Mollusca, Entomostraca, and other fossils of Holland and Belgium, on which he has been so long and successfully engaged.

Report of the Library and Museum Committee, 1867–68.

The Museum.

The additions made to the Foreign portion of the Society's Museum during the past year include a collection of fossils from the Oxfordian and Callovian strata of Poland, presented by M. Zeuschner; a collection of rocks, fossils, and specimens of coal from the Eastern Hemisphere, presented by Dr. C. Collingwood, F.L.S.; a collection of fossil Corals from Trinidad, presented by Dr. P. Martin Duncan, Sec. G.S.; a collection of Devonian fossils from the Rhenish Provinces, presented by the late W. J. Hamilton, Esq., F.R.S., F.G.S.; and single specimens from St. Helena, presented by J. H. Blofeld, Esq., F.G.S.; as well as from the Sewalik Hills, presented by Capt. F. G. S. Parker, F.G.S.; and from Sombrero, presented by H. W. Bristow, Esq., F.R.S., F.G.S.

Among the specimens in the British portion of the Museum, which have been received during the year, are a collection of rocks from Bala, presented by H. T. Richardson, Esq.; and a collection of fossils from the Lingula Flags and Tremadoc Slates, presented by T. Ash,

Esq. In this portion of the Museum the naming and remounting of the collection of Red Crag fossils has been completed, and the re-arrangement of the collection of Eocene fossils has been commenced.

More attention, however, has been given to the Foreign portion of the Museum: in the earlier part of the year the collections of Cretaceous fossils from Faxoe, of Miocene and Pliocene fossils from Italy, and of Senonian, Cenomanian, and Neocomian fossils from France, were cleaned, remounted, and to a great extent renamed. These extra-British fossils occupy 13 drawers, and represent the work done in the Foreign portion of the Museum from the last Anniversary until the close of last Session,—the work in the Museum having been since temporarily suspended, chiefly owing to Mr. Tate's resignation in the summer.

The Committee wish to reexpress the opinion of the standing Library and Museum Committee, given at the close of last Session, as to the desirability of the Society possessing specimens in illustration of papers published in the Quarterly Journal, and to suggest that in future the Assistant Secretary's letter, acknowledging the receipt of communications to the Society, should contain the following paragraph :—

> "The Society would be glad to receive and arrange in their Museum any specimens which you can spare to illustrate your paper."

While on this part of the subject, this Committee beg to recommend that the Library and Museum Assistants, under the direction of the Assistant-Secretary, should, as far as possible, select and separately arrange such specimens in the Museum as have been already presented in illustration of papers read before the Society and published in their Transactions and Quarterly Journal.

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J. GWYN JEFFREYS.
THOS. WILTSHIRE.
ROBERT ETHERIDGE.

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The Library.

The additions to the Library during the year by purchases made at the recommendation of the standing Library Committee include the following works :—

Angelin's 'Iconographia Crustaceorum Formationis Transitionis,' Delbos et Koechlin-Schlumberger's 'Description Géologique et Minéralogique du département du Haut-Rhin,' Quenstedt's 'Handbuch der Petrefactenkunde,' Helmersen's 'Carte Géologique de la Russie,' Herrmannsen's 'Indicis Generum Malacozoorum primordia,' Senft's 'Die krystallinischen Felsgemeintheile,' Fraas's 'Aus dem Orient,' Vogelsang's 'Philosophie der Geologie und mikroskopische Gesteinsstudien,' 'Report of the Geological Survey of Illinois,' the 'Journal de Conchyliologie' from the commencement, and other publications.

The Library has also been enriched by several presents, including

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the publications of numerous Societies and Academies, as well as
the following books:—

Barrande's 'Céphalopodes Siluriens de la Bohême,' Introduction,
'Ptéropodes Siluriens de la Bohême,' Introduction, 'Système Silurien
de la Bohême,' première Partie, 'Recherches Paléontologiques,'
vol. ii., 'Classe des Mollusques, Ordre des Céphalopodes,' vol. iii.,
'Ordre des Ptéropodes,' presented by the author; Da Costa's 'Gaste-
ropodes dos depositos terciarios de Portugal,' presented by the au-
thor; Hochstetter's 'New Zealand,' German and English editions,
presented by the author; Falconer's 'Palæontographical Memoirs,'
2 vols., edited by Dr. Murchison, presented by the editor; Darwin's
'Animals and Plants under Domestication,' presented by the author;
Tchihatcheff's 'L'Asie Mineure et l'Empire Ottoman,' presented by
the author; Favre's 'Savoie,' presented by the author; second
volume of 'Reise der Oesterreichischen Fregatte Novara um die
Erde,' presented by the Austrian Government.

The Map-collection has received numerous additions during the
year, especially Naumann's 'Geognostische Karte des erzgebir-
gischen Bassins im Königreiche Sachsen,' presented by the author;
Koechlin-Schlumberger's 'Carte Géologique du département du
Haut-Rhin,' presented by the author; the Geological-Survey maps
of Great Britain, the Netherlands, Sweden, New Zealand, and
Victoria, presented by the Directors of the respective Surveys;
several sheets of the Ordnance-Survey map of Great Britain, pre-
sented by the Director of the Ordnance Survey, Col. Sir Henry
James; and a large series of French charts, presented by the
Dépôt de la Marine.

The Committee desire to express their regret at the resignation
of Mr. Horace Woodward, who for a period of three years faith-
fully and satisfactorily discharged his duties as Library Assistant.

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J. GWYN JEFFREYS.
THOS. WILTSHIRE.
ROBERT ETHERIDGE.

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*Comparative Statement of the Number of the Society at the close of
the years* 1866 *and* 1867.

	Dec. 31, 1866.		Dec. 31, 1867.
Compounders	186	......	197
Contributing Fellows......	429	......	469
Non-contributing Fellows..	449	......	434
	1064		1100
Honorary Members	3	......	3
Foreign Members	42	......	42
Foreign Correspondents	40	......	40
	1149		1185

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c., at the close of the years 1866 and 1867.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1866	1064
Add Fellows elected during former year and paid in 1867	5
Add Fellows elected and paid in 1867	55
	1124

Deduct Compounders deceased..............	2	
Contributing Fellows deceased	6	
Non-contributing Fellows deceased ..	14	
Contributing Fellows resigned	2	
		24
		1100

Number of Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1866	85	
Add Foreign Member elected	1	
Foreign Correspondent elected	1	
	87	

Deduct Foreign Member deceased 1		
Foreign Correspondent elected as Foreign Member 1		
	2	
		85
		1185

Deceased Fellows.

Compounders (2).

A. J. Sutherland, Esq. | Henry Coles, Esq.

Residents and other Contributing Fellows (6).

H. P. Hakewill, Esq. | Sir T. Phillips.
E. Hopkins, Esq. | W. J. Hamilton, Esq.
Earl of Rosse. | Dr. E. H. Birkenhead.

Non-contributing Fellows (14).

Rev. W. D. Longlands. | J. Smith, Esq. (Jordan Hill).
E. O'Reiley, Esq. | Rev. R. Hankinson.
Very Rev. R. Dawes. | Major Charters.
J. P. Selby, Esq. | Dr. J. Black.
E. Cavell, Esq. | J. P. Fraser, Esq.
Dr. A. Gesner. | Rev. R. Moore.
Rev. B. E. Lampet. | Dr. Daubeny.

<center>*Foreign Member* (1).</center>
<center>Cav. A. Parolini.</center>

<center>FELLOWS RESIGNED (2).</center>

<center>*Residents and other Contributing Fellows.*</center>

G. Lowe, Esq. | G. F. M. Esmeade, Esq.

*The following Personage was elected from the list of Foreign Corre-
spondents to fill the vacancy in the list of Foreign Members during
the year* 1867.

<center>Prof. A. Daubrée, of Paris.</center>

*The following Personage was elected a Foreign Correspondent during
the year* 1867.

<center>Prof. B. Cotta, of Freiberg.</center>

The following Persons were elected Fellows during the year 1867.

January 9th.—George Clark, Esq., Dowlais; James Eccles, Esq.,
  Springwell House, Blackburn; William Harris, Esq., M.A.,
  Osborne Villas, Windsor; and J. Charles Pooley, Esq., F.R.C.S.,
  1 Raglan Circus, Weston-super-Mare.
—— 23rd.—The Rev. George Deane, B.A., B.Sc., Harrold, Bed-
  fordshire; J. Gledhill, Esq., F.M.S., King's Cross, Halifax, York-
  shire; and James Parker, Esq., Oxford.
February 6th.—R. G. M. Browne, Esq., Admiralty Registry, Doc-
  tors' Commons, 9 College Crescent, Hampstead, N.W.; The Rev.
  Michael Alfred Moon, Cleator, near Whitehaven; and Benjamin
  B. Orridge, Esq., 33 St. John's Wood Park, N.W.
—— 20th.—The Right Hon. the Earl de Grey and Ripon, 1 Carlton
  Gardens, S.W.; Frank Clarkson, Esq., 27 Oakley Street, S.W.;
  James Diggens, Esq., Secretary to the Royal Albert Idiot Asylum;
  and Joseph Lucas, Esq., Geological Survey of Great Britain,
  Museum, Jermyn Street, S.W.
March 6th.—Robert Henry Scott, Esq., Hon. Sec. R.G.S.I., Director
  of the Meteorological Department of the Board of Trade; and
  Elijah Walton, Esq., 144 New Kent Road, S.E.
—— 20th.—James Danford Baldry, Esq., 2 Queen's Square, West-
  minster, S.W.; and Coutts Trotter, Esq., 16 Cadogan Place, S.W.
April 3rd.—The Rev. John Edward Cross, M.A., F.R.A.S., Vicar of
  Appleby, Lincolnshire; Elias Dorming, Esq., M.I.C.E., 41 John
  Dalton Street, Manchester; R. Bruce Foot, Esq., Geological Sur-
  vey of India, Calcutta; the Rev. Charles Fraser, M.A., Christ-
  church, New Zealand; Lieut. Luard, R.E., Windsor; John Noble,
  Esq., 51 Westbourne Terrace, Hyde Park, W.; George Spencer
  Percival, Esq., Severn House, Henbury, Bristol; Thomas Richards,
  Esq., Mining Engineer, Bank House, Redruth, Cornwall; Charles

Ricketts, M.D., 22 Argyll Street, Birkenhead; Wilfrid H. Hudleston, Esq., M.A., F.Z.S., J.P., Barrister-at-Law, 21 Gloucester Place, Portman Square, W.; and Josiah Henry Trimellen, Esq., Mining Engineer, 2 Calvert Terrace, Swansea.

April 17th.—John Francis Walker, Esq., B.A., F.C.S., Sidney-Sussex College, Cambridge.

May 8th.—H. Cooper Rose, M.D., F.L.S., Hampstead, N.W.

—— 22nd.—Elias J. Beor, Esq., Mining Engineer, Swansea; Harmer Edward Moore, Esq., C.E., 66 St. George's Road, Belgravia, S.W.; Henry Alleyne Nicholson, Esq., B.Sc., 18 Nicolson Street, Edinburgh; Henry Waugh, Esq., C.E., Gainsborough, Lincolnshire; and the Rev. Francis Le Grix White, M.A., Croxton Parsonage, Eccleshall, Staffordshire.

June 5th.—Augustus Wollaston Franks, Esq., F.R.S., F.S.A., Keeper of Antiquities, British Museum, W.C.

—— 19th.—William T. Lewis, Esq., Aberdare, South Wales.

November 6th.—Nathaniel Plant, Esq., De Montfort House, Leicester; Colonel Lane Fox, F.S.A., late Grenadier Guards; G. F. H. Ulrich, Esq., Geological Survey of Victoria, Melbourne, Victoria; J. Ince, Esq., 26 St. George's Place, Hyde-Park Corner, S.W.; and the Rev. T. S. Woollaston, M.A., Exford, Devonshire.

—— 20th.—Sir Augustus William Denys, Bart., of Easton Neston, Northamptonshire; and Septimus P. Moore, LL.B., 5 St. John's Park Villas, Haverstock Hill, N.W.

December 4th.—William Carruthers, Esq., F.L.S., Department of Botany, British Museum, and 25 Wellington Street, Islington, N.; Charles Evans, Esq., 3 Devonshire Hill, Hampstead; Archibald Hamilton, Esq., South Barrow, Bromley, Kent; Herbert Kirkhouse, Esq., Aberdare, South Wales; Major Edward Owen Leggatt, Staff Corps; John Dalman Orchard, Esq., Teighmohr, Sandford, Cheltenham; Thomas Parton, Esq., Mining Engineer, Willenhall, Wolverhampton; John Burham Safford, Esq., Stow-on-the-Wold; Henry Palfrey Stephenson, Esq., M.I.C.E., 15 Abingdon Street, Westminster; and Ezekiel Williamson, Esq., 6 Goodier's Lane, Regent's Road, Salford.

—— 18th.—T. Jones, Esq., 13 Dundas Terrace, Hampstead; James Wood Mason, Esq., Queen's College, Oxford; Martin Crofton Morrison, Esq., late H.M. Consul in China; the Rev. Thomas Nicholas, M.A., Ph.D., 3 Craven Street, Strand; Arthur Sopwith, Esq., 103 Victoria Street, Westminster; and Marriott Ogle Tarbotton, Esq., M.I.C.E., Newstead Grove, Nottingham.

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

British Specimens.

A collection of Fossils from the Lingula-flags and Tremadoc Slates;
presented by T. Ash, Esq.

Microscopic Slide of Fossil Wood, from the Permian, Ashby; pre-
sented by T. Rylands, Esq., F.G.S.

Nodule from the Valley of Lledoer, North Wales; presented by
W. J. B. Smith, Esq.

Rock-specimens from Bala; presented by H. T. Richardson, Esq.

Foreign Specimens.

A collection of Devonian Fossils from the Rhenish Provinces; pre-
sented by W. J. Hamilton, Esq., F.R.S., F.G.S., &c.

A collection of Fossils from the Oxford and Kelloway strata in
Poland; presented by M. Zeuschner, per Alfred Evans, Esq.

A collection of Rocks, Fossils, and specimens of Coal from the Eastern
Hemisphere; presented by Cuthbert Collingwood, M.B., F.L.S.

Coral from St. Helena, dredged at a depth of 360 fms.; presented
by J. H. Blofeld, Esq.

Fossil Bone from above the Mohund Pass, Sewalik Hills; presented
by Capt. F. G. S. Parker, F.G.S.

Specimen of Sombrerite (Phosphate of Lime) from the Island of
Sombrero; presented by H. W. Bristow, Esq., F.R.S., F.G.S., &c.

Cretaceous Fossils from South Africa; presented by Major Garden,
F.G.S.

MAPS, CHARTS, ETC., PRESENTED.

Carte Géologique du département du Haut-Rhin, par Joseph Koech-
lin-Schlumberger, 1866, with two Sheets of Sections; presented
by the author.

Chart of Characteristic British Tertiary Fossils (chiefly Mollusca),
stratigraphically arranged, compiled by J. W. Lowry, with the
assistance of R. Etheridge and F. E. Edwards; presented by
J. W. Lowry, Esq.

Charts and Plans of the Coast of Various Parts of the World, pub-
lished by the Dépôt de la Marine de la France; presented by the
Dépôt de la Marine.

Geognostische Karte des ehemaligen Gebietes von Krakau, mit dem
südlich angrenzenden Theile von Galizien, von Ludwig Hohenegger;
presented by the author.

Geognostische Karte des erzgebirgischen Bassins im Königreiche
Sachsen, von Prof. Carl Naumann, Section I. Oestliche Hälfte.
Section II. Westliche Hälfte, 1866; presented by the author.

Geological Sketch-map of the Northern District of the Province of
Auckland, by James Hector, M.D., F.G.S., Director of the Geo-
logical Survey of New Zealand; presented by the author.

Geological-Survey maps of Great Britain, Sheet 8; presented by the Director-General of the Geological Survey of the British Isles.

Geological-Survey maps of the Netherlands, Nos. 22, 27; presented by His Excellency the Ambassador for the Netherlands.

Geological-Survey maps of Sweden, Nos. 19–21, with accompanying explanations; presented by Prof. A. Erdmann.

Geological-Survey maps of Victoria, Nos. 15, 51; presented by the Director, A. R. C. Selwyn, Esq.

Geologische Uebersichtskarte der österreichischen Monarchie, by F. R. von Hauer; presented by the author.

Geologische Karten des Grossherzogthums Hessen; herausgegeben von dem mittelrheinischen geologischen Vereins, von A. Grooss und R. Ludwig; presented by the Middle Rhine Geological Society.

Ordnance-Survey maps of England, 1-inch scale, Sheets 105, 106: 6-inch scale, Cumberland, Sheets 49–53, 55, 56, 60, 67, 68, 70–72, 74; presented by the Director-General of the Survey.

Ordnance-Survey maps of Ireland, 1-inch scale, Sheets 13, 27, 129; presented by the Director of the Survey.

Ordnance-Survey maps of Scotland, 1-inch Scale, Sheet 24: 6-inch scale, Perthshire, Sheets 34, 42–44, 46, 48, 49, 52–58, 60–64, 66–70, 75, 87, 91, 92, 113; presented by the Director of the Survey.

The following Lists contain the Names of Persons and Public Bodies from whom the Society has received Donations to the Library and Museum since the last Anniversary, February 15, 1867.

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

Bath, Natural History and Antiquarian Field Club.

Berlin. German Geological Society.

——. Royal Prussian Academy.

——. Saxon and Thuringian Natural-History Society.

Berwick. Northumberland and Durham Natural-History Society.

Bonn. Royal Leopold-Caroline Academy.

Bordeaux, Society of Physical and Natural Sciences of.

Brussels. Royal Academy of Belgium.

——, Royal Observatory of.

Calcutta. Asiatic Society of Bengal.

Christiania, Royal Academy of.

——, University of.

Copenhagen. Royal Danish Academy.

Darmstadt. Geological Society of the Middle Rhine.

Dijon, Academy of.

Dresden, Natural History Society of.

Dublin. Geological Survey of Ireland.

——. Royal Irish Academy.

Edinburgh, Royal Society of.

Essex Institute, U.S.

Geneva, Physical and Natural History Society of.

Glasgow, Geological Society of.

Halle, Society of Natural Sciences of.

Hesse, Natural-History Society of.

Lausanne. Vaudoise Society of Natural Sciences.
Leeds. Philosophical and Literary Society.
Liége, Royal Society of Sciences of.
Liverpool, Geological Society of.
——. Lancashire and Cheshire Historic Society.
London, Anthropological Society of.
——. British Association.
——. British Museum.
——. Chemical Society.
——. Geological Survey of Great Britain.
——. Institution of Civil Engineers.
——. Linnean Society.
——. Microscopical Society.
——. Palæontographical Society.
——. Photographic Society.
——. Ray Society.
——. Royal College of Surgeons.
——. Royal Geographical Society.
——. Royal Horticultural Society.
——. Royal Institution.
——. Royal Society.
——. Society of Arts.
——. War Office.
——, Zoological Society of.
Lyons, Royal Academy of.

Manchester, Geological Society of.
Melbourne. Geological Survey of Victoria.

Melbourne. Mining Survey of Victoria.
——. Royal Society of Victoria.
Milan. Royal Lombard Institute.
Montreal. Geological Survey of Canada.
Munich, Royal Academy of.

Palermo. Institute of Natural Sciences.
Paris. Academy of Sciences.
——. Dépôt Général de la Marine.
——. Geological Society of France.
——, Museum of Natural History of.
Philadelphia, Academy of Natural Sciences of.
Presburg, Natural-History Society of.

St. Petersburg, Academy of Sciences of.
Stuttgart. Natural-History Society of Würtemberg.
Sweden, Geological Survey of.

Trinidad, Scientific Association of.
Turin, Royal Academy of Science of.

Vienna, Imperial Academy of Sciences of.
——, Geological Institute of.
——, Zoologico-Botanical Society of.

Warwickshire Natural-History and Archæological Society.
Washington. Smithsonian Institution.

Yorkshire, Geological and Polytechnical Society of the West Riding of.

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

Abich, Dr. H.
American Journal of Mining, Editor of the.
American Journal of Science, Editor of the.
Annales des Mines, Editors of the.
Annals and Magazine of Natural History, Editors of the.
Aoust, M. V. d'.
Archiac, M. d', F.M.G.S.
Athenæum Journal, Editor of the.

Baily, W. H., Esq., F.G.S.
Bakewell, F. C., Esq.
Barlow, Dr. H. C., F.G.S.
Barrande, M. J., F.M.G.S.
Béron, M. P.
Bett, J., Esq., F.G.S.
Bischoff, Dr. G., F.M.G.S.
Blake, W. P., Esq.
Blanford, W. T., Esq., F.G.S.
Brandt, Dr. J. F.
Briart, M.
Bristow, H. W., Esq., F.G.S.
Brodie, Rev. P. B., F.G.S.
Browne, R. G. M., Esq., F.G.S.
Burmeister, Dr. G.

Canadian Journal, Editors of the.
Canadian Naturalist and Geologist, Editors of the.
Carpenter, Dr. W. B., F.G.S.
Chemical News, Editor of the.
Christy, H., Esq., F.G.S., Executors of the late.
Clarke, Rev. W. B., F.G.S.
Colliery Guardian, Editor of the.
Cornet, M.
Crawford, Hon. J. C., F.G.S.

Da Costa, Señor P.
Darwin, C., Esq., F.G.S.
Daubeny, Dr. C., F.G.S.
Daubrée, Prof. A., F.M.G.S.

Dawson, Dr. J. W., F.G.S.
Delesse, M., F.M.G.S.
Duncan, Dr. P. Martin, Sec. G.S.

Eichwald, Dr. E. von.
Erdmann, Dr.

Fairman, C. St. John, Esq., F.G.S.
Falconer, C., Esq., F.G.S.
Faudel, M. le Dr.
Favre, M. A.
Floral World, Editor of the.
Foreign Affairs, Secretary of State for.
Francis, Dr., F.G.S.

Garrigou, Dr. F. A. F.
Gaudry, M. A.
Gaussan, M. E.
Geikie, A., Esq., F.G.S.
Geological and Natural-History Repertory, Editor of the.
Geological Magazine, Editors of the.
George, Staff-Commander.
Gibb, Sir G. Duncan, F.G.S.
Greppin, Dr.
Grewingk, Dr. C. von.
Griffith, W., Esq.

Hall, J., Esq., F.M.G.S.
Hardwicke and Co., Messrs.
Hauer, F. Ritter von, F.C.G.S.
Helmersen, General G. von, F.M.G.S.
Hochstetter, Dr. F. von.
Hunt, Dr. J.
Hunt, R., Esq.

Intellectual Observer, Editor of the.

Jeffcock, C., Esq.
Jeffreys, J. G., Esq., Treas. G.S.
Jones, Prof. T. R. F.G.S.

Journal of Natural and Economic
  Science, Palermo, Editor of
  the.

Karrer, Dr. F.
Kirkby, J. W., Esq.

Lang, Prof. V. von.
Lartet, M. E., F.M.G.S.
Laube, Dr. G. C.
Lee, Isaac, Esq.
Lemberg, J. von.
Lindström, Dr. G.
Logan, Sir W. E., F.G.S.
London, Edinburgh, and Dublin
  Philosophical Magazine, Editors
  of the.
London Review, Editor of the.
Longman and Co., Messrs.
Lowry, J. W., Esq.
Ludwig, Dr. R. von.
Lyell, Sir C., Bart., F.G.S.

Mackie, S. J., Esq., F.G.S.
McCoy, Prof. F., F.G.S.
Marsh, Prof. O. C., F.G.S.
Medical Press and Circular,
  Editor of the.
Möller, Dr. F. von.
Moore, C., Esq., F.G.S.
Murchison, Sir R. I., Bart., F.G.S.

Naumann, Dr. C., F.M.G.S.
Nielreich, Dr. A.

Oldham, Dr. T., F.G.S.
Omboni, Sign. M. G.
Ormerod, G. W., Esq., F.G.S.

Packard, Dr. A. S.
Patti, Sign. C. S.
Pattison, S. R., Esq., F.G.S.
Perrey, M. A.

Photographic Journal, Editor of
  the.
Poli, Prof. B.

Quarterly Journal of Microscopic
  Science, Editors of the.
Quarterly Journal of Science,
  Editors of the.

Renevier, M. E.
Reuss, Prof. A. E., F.C.G.S.
Ribeiro, M. C.
Rose, Prof. G., F.M.G.S.
Rütimeyer, Dr. L.

Sandberger, Dr. F., F.C.G.S.
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Tate, R., Esq., F.G.S.
Tennant, Prof. J., F.G.S.
Thomas, J. E., Esq., F.G.S.
Thomson, J., Esq., F.G.S.
Traill, G. W., Esq.
Trübner and Co., Messrs.

Victoria, Chief Secretary of.
Visiani, Prof. R. de.
Vose, G. L., Esq.

War, Secretary of State for.
Whitaker, W., Esq., F.G.S.
Whitfield, R. P., Esq.

Young, J., Esq., F.G.S.

Zigno, Baron A. de, F.C.G.S.

List of PAPERS *read since the last Anniversary Meeting,*
February 15*th,* 1867.

1867.

February 20th.—On the British Fossil Oxen.—Part II. *Bos longifrons,* Owen, by W. Boyd Dawkins, Esq., M.A. (Oxon), F.R.S., F.G.S.

———————— On the Geology of the Upper Part of the Valley of the Teign, Devonshire, by G. W. Ormerod, Esq., M.A., F.G.S.

———————— Notes on the geological features of Mauritius, by George Clark, Esq.,; communicated by H. M. Jenkins, Esq., F.G.S.

March 6th.—On Ancient Sea-marks on the coast of Sweden, by the Right Hon. the Earl of Selkirk, F.R.S., F.G.S.

———————— On a Posttertiary Lignite, or Peat-bed, in the District of Kintyre, Argyllshire, by His Grace the Duke of Argyll, K.T., F.R.S., F.G.S.

March 20th.—Report on recent discoveries of Gold in New Brunswick, by W. S. Shea, Esq.; communicated by the Right Hon. the Earl of Carnarvon.

———————— On the discovery of coal on the Eastern Slope of the Andes, by W. Wheelwright, Esq.; communicated by Sir R. I. Murchison, Bart., F.R.S., F.G.S.

———————— On the presence of Purbeck Beds at Brill, Buckinghamshire, by the Rev. P. B. Brodie, M.A., F.G.S.

———————— On the Lower Lias or Lias Conglomerate of Glamorganshire, by H. W. Bristow, Esq., F.R.S., F.G.S.

———————— On Abnormal conditions of Secondary Deposits when connected with the Somersetshire and South Wales Coal-basins; and on the age of the Sutton and Southerndown Series, by C. Moore, Esq., F.G.S.

April 3rd.—Remarks on the Drift in a part of Warwickshire, and on the evidence of glacial action which it affords, by the Rev. P. B. Brodie, M.A., F.G.S.

———————— On the dentition of *Rhinoceros leptorhinus* (Owen), by W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S.

———————— On the Strata which form the base of the Lincolnshire Wolds, by J. W. Judd, Esq., F.G.S.

April 17th.—On the Physical Structure of North Devon and on the Palæontological Value of the Devonian Fossils, by R. Etheridge, Esq., F.R.S.E., F.G.S.

May 8th.—On new specimens of *Eozoon,* by Sir W. E. Logan, F.R.S., F.G.S.

———————— Notes on Fossils recently obtained from the Laurentian rocks of Canada, and on objections to the organic nature of *Eozoon,* by J. W. Dawson, LL.D., F.R.S., F.G.S.

———————— On Subaërial Denudation, and on Cliffs and Escarpments of the Chalk and Tertiary Strata, by W. Whitaker, Esq., B.A., F.G.S.

1867.

May 22nd.—On the Bone-caves near Crendi, Zebbug, and Melhiha, in the Island of Malta, by Capt. T. A. B. Spratt, R.N., C.B., F.R.S., F.G.S.

——————— On the Lower Lias of the North-east of Ireland, by R. Tate, Esq., A.L.S., F.G.S.

——————— On the fossiliferous development of the zone of *Ammonites angulatus* in Great Britain, by R. Tate, Esq., A.L.S., F.G.S.

——————— On the Rhætic Beds near Gainsborough, by T. M. Burton, Esq., F.G.S.

——————— The Alps and the Himalayas, a Geological Comparison, by H. B. Medlicott, Esq., A.B., F.G.S.

——————— On some striking Instances of the Terminal Curvature of Slaty Laminæ in West Somerset, by D. Mackintosh, Esq., F.G.S.

June 19th.—On *Cyclocyathus*, a new genus of the *Cyathophyllidæ*, with remarks on the genus *Aulophyllum*, by P. Martin Duncan, M.B., Sec. G.S., and James Thomson, Esq.

——————— On the discovery of a new Pulmonate Mollusk (*Conulus priscus*, P. P. Carpenter) in the Coal-formation of Nova Scotia, by J. W. Dawson, LL.D., F.R.S., F.G.S.

——————— On some tracks of *Pteraspis* (?) in the Upper Ludlow Sandstone, by J. W. Salter, A.L.S., F.G.S.

——————— On a new *Lingulella* from the Red Lower Cambrian Rocks of St. David's, by J. W. Salter, Esq., A.L.S., F.G.S., and H. Hicks, M.D.

——————— Observations on certain Points in the Dentition of Fossil Bears, which appear to afford good diagnostic characters, and on the relation of *Ursus priscus*, Goldf., to *U. ferox*, by G. Busk, Esq., F.R.S., F.G.S.

——————— On the Geology of the province of Canterbury, New Zealand, by J. Haast, M.D., F.R.S., F.G.S.; communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.

——————— On the Chemical Geology of the Malvern Hills, by the Rev. H. Timins, M.A., F.G.S.

——————— On the Relative Distribution of Fossils throughout the North Devon Series, by T. M. Hall, Esq., F.G.S.

——————— On the Geology of the Princes Islands in the Sea of Marmora, by W. R. Swan, Esq.; communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S., &c.

——————— On the Sulphur-Springs of Northern Formosa, by C. Collingwood, M.B., F.L.S.; communicated by Dr. J. D. Hooker, F.G.S.

——————— On the Geology of Benghazi, Barbary, with an account of the subsidences in its vicinity, by G. B. Stacey, Esq., communicated by the President.

——————— Report on the Existence of large Coal-fields in the Province of St. Catherine's, Brazil, by E. Thornton, Esq.; communicated by the Right Hon. the Secretary of State for Foreign Affairs.

1867.

June 19th.—On the sources of the materials composing the White Clays of the Lower Tertiaries, by George Maw, Esq., F.L.S., F.G.S.

———————— On the Postglacial Structure of the South-east of England, by Searles V. Wood, Jun., Esq., F.G.S.

November 6th.—On the Amiens Gravel, by A. Tylor, Esq., F.L.S., F.G.S.

November 20th.—On the Glacial and Postglacial Structure of Lincolnshire and South-east Yorkshire, by S. V. Wood, Jun., Esq., F.G.S., and the Rev. J. L. Rome, F.G.S.

———————— On supposed Glacial markings in the Valley of the Exe, North Devon, by N. Whitley, Esq.

———————— On Disturbance of the Level of the Land near Youghal in the South of Ireland, by A. B. Wynne, Esq., F.G.S.

December 4th.—On the Graptolites of the Skiddaw Series, by Henry A. Nicholson, D.Sc., M.B., F.G.S.

———————— On the Fossil Corals (*Madreporaria*) of the West-Indian Islands.—Part IV. Conclusion, by P. Martin Duncan, M.B., Sec. G.S.

December 18th.—On the Parallel Roads of Glen Roy, by Sir John Lubbock, Bart., F.R.S., Pres. Ent. Soc., F.G.S.

———————— Remarks on the Geological Features of the Northern part of Formosa, by C. Collingwood, M.B., F.L.S. ; communicated by H. M. Jenkins, Esq., F.G.S.

———————— On some Sources of Coal in the Eastern Hemisphere, by C. Collingwood, M.B., F.L.S. ; communicated by H. M. Jenkins, Esq., F.G.S.

1868.

January 8th.—Notes on the Lower Lias of Bristol, by W. W. Stoddart, Esq., F.G.S.

———————— On the Lower Lias beds occurring at Cotham, Bedminster, and Keynsham, near Bristol, by C. O. Groom-Napier, Esq., F.G.S.

———————— On the Dentition of *Rhinoceros Etruscus*, Falc., by W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S.

January 22nd.—On the Speeton Clay, by J. W. Judd, Esq., F.G.S.

———————— Notice of the Hessle Drift as it appeared in Sections more than forty years since, by Prof. John Phillips, D.C.L., F.R.S., F.G.S.

February 5th.—On the Geology of Argyllshire, by His Grace the Duke of Argyll, K.T., D.C.L., F.R.S., 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 Warington W. Smyth, Esq., retiring from the office of President.

2. That the thanks of the Society be given to Sir Philip de M. Grey Egerton, Bart., M.P., Sir Charles Lyell, Bart., and J. Carrick Moore, Esq., retiring from the office of Vice-President.

3. That the thanks of the Society be given to Joseph Prestwich, Esq., retiring from the office of Treasurer.

4. That the thanks of the Society be given to R. A. C. Godwin-Austen, Esq., retiring from the office of Foreign Secretary.

5. That the thanks of the Society be given to R. A. C. Godwin-Austen, Esq., H. W. Bristow, Esq., the Earl of Enniskillen, Dr. Meryon, J. Carrick Moore, Esq., Joseph Prestwich, Esq., and Capt. T. A. B. Spratt, R.N., C.B., 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 :—

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Rev. T. Wiltshire, M.A., F.L.S.

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TREASURER.
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Sir Charles Lyell, Bart., D.C.L., F.R.S.
Prof. John Morris.
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Robert W. Mylne, Esq., F.R.S.
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Earl of Selkirk, F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Alfred Tylor, Esq., F.L.S.
Rev. T. Wiltshire, M.A., F.L.S.
Searles V. Wood, Jun., Esq.
Henry Woodward, Esq., F.Z.S.

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OF THE GEOLOGICAL SOCIETY OF LONDON, in 1868.

Date of
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1822. Count Vitaliano Borromeo, *Milan.*
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1829. Dr. J. J. d'Omalius d'Halloy, *Halloy, Belgium.*
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.*
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1844. William Burton Rogers, Esq., *Boston, U.S.*
1844. M. Edouard de Verneuil, For. Mem. R.S., *Paris.*
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1848. James Hall, Esq., *Albany, State of New York.*
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1850. Herr Hermann von Meyer, *Frankfort-on-Maine.*
1851. Prof. James D. Dana, *New Haven, Connecticut.*
1851. General G. von Helmersen, *St. Petersburg.*
1851. Dr. W. K. von Haidinger, For. Mem. R.S., *Vienna.*
1851. Professor Angelo Sismonda, *Turin.*
1853. Count Alexander von Keyserling, *Dorpat.*
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1854. M. Joachim Barrande, *Prague.*
1854. Prof. Carl Friedrich Naumann, *Leipsic.*
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1857. Prof. H. R. Goeppert, *Breslau.*
1857. M. E. Lartet, *Paris.*
1857. Prof. H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *Tiflis, Georgia.*
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1859. Prof. A. Delesse, *Paris.*
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1860. Dr. H. Milne-Edwards, For. Mem. R.S., *Paris.*
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1865. M. Jules Desnoyers, *Paris.*
1866. Dr. Joseph Leidy, *Philadelphia.*
1867. Prof. A. Daubrée, *Paris.*

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1863. Prof. E. Beyrich, *Berlin.*
1863. M. Boucher de Perthes, *Abbeville.*
1863. Herr Bergmeister Credner, *Gotha.*
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1863. Rev. Dr. O. Heer, *Zurich.*
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1863. M. Lovén, *Stockholm.*
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ESTABLISHED BY

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1867. Mr. W. H. Baily.
1868. M. J. Bosquet.

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Due for Arrears (See Valuation-sheet)	370	0	0			
				440	0	0
Estimated Ordinary Income for 1868.						
Annual Contributions:						
From Resident Fellows, &c., and Non-residents of 1859 to 1861				730	0	0
Admission-fees (supposed)				200	0	0
Compositions (supposed)				300	0	0
Dividends on Consols				153	0	0
Sale of Transactions, Proceedings, Library-catalogues, and Ormerod's Index	10	0	0			
Sale of Quarterly Journal	160	0	0			
Sale of Geological Map	70	0	0			
				240	0	0
Due from Longman and Co. in June	55	15	1			
Due from Stanford and Co. in June	14	13	0			
				70	8	1

The sum of £322 18s. 5d., which was brought forward as due to Income from the Bequest Fund at the end of 1866, has been settled by the nominal transfer of the remaining £300 invested on account of that Fund. The sums advanced remain therefore charged to ordinary Income, and the £300 remains added to Capital Account.

	£2133	8	1

JOSEPH PRESTWICH, TREAS.

Feb. 3, 1868.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes and Insurance	100	0	0			
House-repairs	20	0	0			
Furniture	15	0	0			
Fuel	36	0	0			
Light	30	0	0			
Miscellaneous Printing, including Abstracts	75	0	0			
Tea for Meetings	20	0	0			
Miscellaneous House-expenses	75	0	0			
Stationery	35	0	0			
				406	0	0
Salaries and Wages:						
Assistant-Secretary	300	0	0			
Clerk	80	0	0			
Assistants in Library and Museum	140	0	0			
Porter	100	0	0			
Housemaid	40	0	0			
Occasional Attendants	10	0	0			
Collector	45	0	0			
Accountant	5	0	0			
				720	0	0
Library	100	0	0			
Museum	20	0	0			
				120	0	0
Diagrams at Meetings				1	4	0
Miscellaneous Scientific Expenditure				60	0	0
Publications: Quarterly Journals	620	0	0			
„ Transactions	5	0	0			
„ Geological Map	50	0	0			
				675	0	0
Balance in favour of the Society				151	4	1
				£2133	8	1

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Banker's January 1, 1867				666	5	9
Ditto in Clerk's hands				52	8	9
Compositions received				267	15	0
Arrears of Admission-fees	31	10	0			
Admission-fees, 1867	321	6	0			
				352	16	0
Arrears of Annual Contributions				114	9	0

Annual Contributions for 1867, viz.:

	£	s.	d.	£	s.	d.
Resident Fellows	635	5	0			
Non-Resident Fellows	29	18	6			
				665	3	6
Annual Contributions in advance				14	14	0
Dividends on Consols				141	12	8

Publications:

	£	s.	d.	£	s.	d.
Sale of Transactions	2	16	6			
Sale of Journal, Vols. 1–22	167	2	9			
,, Vol. 23*	66	19	4			
Sale of Geological Map	51	13	11			
Sale of Library-catalogues	1	5	0			
Sale of Ormerod's Index	1	0	0			
				290	17	6

We have compared the Books and Accounts presented to us, and found them correct.

(Signed)   JAMES TENNANT, } *Auditors.*   £2566   2   2
            THOS. WILTSHIRE, }

Feb. 3, 1868.

	£	s.	d.
* Due from Messrs. Longman, in addition to the above, on Journal, Vol. 23, &c.	55	15	1
Due from Fellows for Journal subscriptions, estimated	40	0	0
Due from Messrs. Stanford on Geological Map	14	13	0
	£110	8	1

EXPENDITURE.

General Expenditure :	£	s.	d.	£	s.	d.
Taxes	64	6	8			
Fire-insurance	9	0	0			
New Furniture	16	15	7			
House-repairs	37	0	1			
Fuel	38	13	0			
Light	29	13	1			
Miscellaneous House-expenses	73	16	11			
Stationery	39	6	7			
Miscellaneous Printing	61	15	6			
Tea at Meetings	20	11	10			
				390	19	3
Salaries and Wages :						
Assistant-Secretary	227	10	0			
Clerk and assistance in Office	100	0	0			
Library and Museum Assistants	129	15	0			
Porter	100	0	0			
Housemaid	40	0	0			
Occasional attendants	8	5	0			
Accountants	5	0	0			
				610	10	0
Library				94	5	1
Museum				2	2	6
Miscellaneous Scientific Expenses				71	6	9
Publications :						
Geological Map	83	7	11			
Transactions	0	1	0			
Journal, Vols. 1–22	82	2	6			
„ Vol. 23	530	14	4			
				696	5	9
Investment in £315 7s. 6d. Consols				300	0	0
Balance at Banker's, Dec. 31, 1867				395	4	6
Balance in Clerk's hands, Dec. 31, 1867				5	8	4

£2566 2 2

TRUST-ACCOUNT.

RECEIPTS.	£	s.	d.		PAYMENTS.	£	s.	d.
Balance at Banker's, January 1, 1867, on the Wollaston Donation-fund	31	19	6		Award to Mr. W. H. Baily	21	9	6
Dividends on the Donation-fund for 1867 on Reduced 3 per Cents.	31	19	6		Cost of striking Gold Medal awarded to Mr. G. Poulett Scrope	10	10	0
					Balance at Banker's (Wollaston-fund)	31	19	6
	£63	19	0			£63	19	0

VALUATION OF THE SOCIETY'S PROPERTY; 31st December, 1867.

PROPERTY.	£	s.	d.		DEBTS.	£	s.	d.
Due from Longman & Co.,on acc. of Journ. Vol. XXIII.,&c.	55	15	1		Balance in favour of the Society	5757	2	5
Due from Subscribers to Journal	40	0	0					
Due for Authors' Corrections in Journal	30	0	0					
Balance in Banker's hands, Dec. 31, 1867 ditto	395	4	6					
Balance in Clerk's hands ditto	5	8	4					
	5116	11	1					
Funded Property:—								
Consols, at 95	4860	14	6					
Arrears of Admission-fees (considered good)	50	8	0					
Arrears of Annual Contributions (ditto)	319	12	0					
	£5757	2	5			£5757	2	5

[*N.B. The value of the Mineral Collections, Library, Furniture, and stock of unsold Publications is not here included.*]

JOSEPH PRESTWICH, *Treas.*

Feb. 3, 1868.

The sum of £300, invested on account of the Bequest Fund and included in the above Account, now stands as part of Income invested, Income having been charged with the expenses incurred on behalf of that Fund, which now ceases to exist; and the expenses of the Geological Map and other work, hitherto defrayed by that Fund, will from this date be charged to Income Account.

PROCEEDINGS

ANNUAL GENERAL MEETING,

21st FEBRUARY, 1868.

AWARD OF THE WOLLASTON MEDAL.

THE Reports of the Council and of the Committees having been read, the President, WARINGTON W. SMYTH, Esq., M.A., F.R.S., handed the Wollaston Medal to Professor D. T. ANSTED, M.A., F.R.S., addressing him as follows :—

Professor ANSTED,—I consider it no common privilege to hand to you for presentation the Wollaston Medal, which has been awarded by the Council to Carl Friedrich Naumann, of Leipzig. If it were needed to set before the Society the important services which have been rendered to our Science by that distinguished geologist, I should point to the list of his published works, and to the great geological map of Saxony, carried out in great part by his own field-surveys, although aided in portions by the cooperation of Professor Cotta and others.

Naumann's early labours date back half a century ago ; and his excellent ' Travels in Norway ' and the sketch of a treatise on rocks (Andeutungen zu einer Gesteinslehre) were published in 1824. From that time forth he has been an active worker in the lecture-room, the mineralogical cabinet, and in the field. His ' Elements of Crystallography,' published in 1826, and his larger work on the same subject, 1830, are, to say the least of them, on a par with the best efforts of the best men ; and these were followed up by his manuals of Mineralogy, the excellent qualities of which are sufficiently proved by their general diffusion through the student-world of Germany, and by their translation into other languages.

His great treatise on Geology (Lehrbuch der Geognosie), of which a new edition has just been completed, is probably the most masterly comprehensive summary of the facts and opinions of our science which has appeared in any country.

His numerous contributions to periodical scientific literature can only be generally referred to ; but I should fail in expressing the great merits of Professor Naumann, were I not to refer to the admirable manner in which for many years he filled the chair of the great Werner, at Freiberg, in Saxony. A quarter of a century has passed since I enjoyed the advantage of hearing his fluent delivery of the encyclopædic knowledge of geological phenomena which he had amassed ; but, both from the lucid method of his lectures and from

the friendly aid with which he furthered the explorations of the students in the field, I can appreciate the immense influence which he has exercised on the practical education of the rising youth of Germany, an influence which has been exercised on a larger scale since he was called to assume the Professorship at Leipzig.

Saxony is a country boasting but a small population; and yet our Society is well aware of the numerous high names in various departments of science of which a Saxon may be proud. In awarding our highest honour to Professor Naumann, I trust that it will be seen that we are truly desirous of seeking out merit wherever it exists, and that we thus testify our sense of the high value of labours carried on without show or blazon, but with a conscientious regard to the interest of scientific truth.

Professor ANSTED, on receiving the Medal, replied as follows:—

Mr. PRESIDENT,—In the absence of Professor Naumann, who is unable at the present season to interrupt his University course, I beg to acknowledge on his behalf the reception of this Medal; and it will be my duty to transmit it to him, accompanied with an intimation of the manner in which the announcement of the Council has been received.

I hold in my hand a letter from Professor Naumann, expressing his own sense of the high honour the Council has awarded him; and a translation of this letter, with your permission, I will now proceed to read.

Leipzig.

Mr. PRESIDENT,—The honourable award of the Gold Wollaston Medal is for me one of the most gladdening events of my life. It is cheering with reference to the past, inasmuch as it offers me the satisfactory consciousness that my former labours in the departments of Mineralogy and Geology have not been conducted without useful results, since they have been deemed worthy of so brilliant a distinction by the highest tribunal of Geological Science. And it is equally cheering with regard to the future, because the recognition shown by so competent a tribunal will lend me in my old age courage and strength to follow up to their completion the tasks which still lie before me.

I feel myself, therefore, bound to express to you, Mr. President, and to all the honoured Members of the Council of the Geological Society, my respectful and deeply felt gratitude, as well as to assure you that I shall do all that lies in my power to prove myself to the end of my days worthy of the distinction which you have conferred upon me.

AWARD OF THE WOLLASTON DONATION-FUND.

The President then addressed R. A. C. GODWIN-AUSTEN, Esq., F.R.S., as follows:—

Mr. GODWIN-AUSTEN,—I have much pleasure in requesting you to send to M. Bosquet, of Maestricht, the balance of the proceeds of the

Wollaston Fund, awarded to him by the Council, in aid of his valuable researches on the Tertiary and Cretaceous strata of Holland and Belgium. It is hoped that this acknowledgment of his services will be an encouragement to M. Bosquet, inciting him to continue those labours which he has for some years with much success carried on during the time snatched from his business avocations.

Mr. GODWIN-AUSTEN replied as follows :—

SIR,—I shall take an early opportunity of transmitting to M. Bosquet, of Maestricht, the proceeds of the Wollaston Fund, accompanied by an assurance of the cordial unanimity with which it was awarded him. The Members of the Geological Society of London cannot fail to entertain a high opinion of the zeal, industry, and ability which have produced M. Bosquet's contributions to Palæontology. Of these, perhaps, the most interesting to us are those relating to the Cretaceous formation of the neighbourhood of Maestricht, the richness of the fauna of which is in striking contrast to that of the equivalent portion in this country.

His researches amongst the so-called Tongrian beds have contributed greatly to our knowledge both of the forms of life and the general character of the physical conditions which closed the great Nummulitic period in that part of Northern Europe.

I may add that geologists who may visit Maestricht will find in M. Bosquet's collection the vouchers for the accuracy of his published works ; and I can speak from experience as to his kindness and readiness in guiding others about a district which, from its covered character, cannot be profitably visited without such assistance.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

WARINGTON W. SMYTH, ESQ., M.A., F.R.S.

It is now, gentlemen, my duty, in accordance with your long-established custom, to enter upon the painful task of reminding you of the loss which we have sustained in the past year by the death of several of our scientific brethren. And, first of all, it behoves me to speak of one unwearied in his devotion to your interests, one endeared by personal friendship to many of us, my immediate predecessor in this honourable Chair.

WILLIAM JOHN HAMILTON was the eldest son of Mr. William Hamilton, some time British Minister at the Court of Naples, a gentleman whose classical tastes and erudition influenced to a considerable extent the career of our late President. He was born in London on the 5th July, 1805, and after an early education at Charterhouse School, passed over to Hanover, and completed his studies at the University of Göttingen. Proposing to devote himself to the diplomatic service, he paid in his youth especial attention to modern languages and history, and in 1827 was appointed attaché to the Legation at Madrid. In 1829 he received a similar appointment in Paris,

and after his return to London acted for some time as *précis*-writer to the Foreign Office, under Lord Aberdeen.

It was owing to the friendship subsisting between Mr. Hamilton's family and Sir Roderick Murchison that the young diplomatist aspired to make himself a geologist, was elected a Fellow of our Society in 1831, and in 1832 entered, in conjunction with Professor Edward Turner, on the joint duties of the Secretaryship.   In March, 1835, he read his first paper, on a bed of recent marine shells occurring near Elie, on the southern coast of Fifeshire (Proc. Geol. Soc. vol. ii.) ; and having had the misfortune to lose his wife, he arranged shortly after this date to undertake a long exploratory journey to the Levant, in company with that estimable man and naturalist, Hugh Strickland, so untimely snatched from life by an accident on a railway.   The main object to be attained was an examination of Asia Minor, of which we possessed extremely little accurate information, in a geographical, geological, and antiquarian point of view. Mr. Strickland returned home, after their joint tour through the Ionian Islands, the neighbourhood of Constantinople, and the Katakekaumene, in 1835–36, whilst Mr. Hamilton proceeded alone on an adventurous series of journeys—first into Armenia, then across the whole length of Asia Minor, from east to west, again into the interior to the great Salt Lakes and the culminating point of the Anatolian mountains, Mount Erjish, which he ascended and determined to be 13,000 feet in height, and, further touching on the flanks of the south-eastern Taurus and returning westward by another route to Smyrna.

Some of the more important geological observations collected during this protracted riding-tour were communicated to the Society in a paper published in the 'Transactions,' 2nd Ser. vol. v., treating of the country between the trachytic peak of Hassan Dagh and the salt lake of Kodj-hissar, and of the district around Kaisariyeh, including Erjish Dagh, the ancient Argæus.   Further papers connected with these regions were :—the "Account of a Tertiary deposit near Lixouri, in the island of Cephalonia" (Proceedings, vol. ii.) ; a general description of the Geology of the north-western part of Asia Minor, from the peninsula of Cyzicus, on the coast of the sea of Marmora, with a full notice of the Katakekaumene, that district so well named the "burnt-up," of whose extensive craters and lava-streams we thus obtained a lively picture.

A portion of his wanderings in the Levant led to another paper, published in the 'Proceedings,' vol. iii., "On a few detached places along the coast of Ionia and Caria, and in the island of Rhodes ;" but the entire journey was described fully in his 'Researches in Asia Minor, Pontus, and Armenia,' published in two volumes in 1842.   Mr. Hamilton adopted the narrative style of description, as most suitable to long lines of examination carried through a country of which even the geography was extremely vague ; and the various archæological and natural-history details are thus mingled throughout as they happened to take their place in the diary.   The disposition of the author, good-humoured, pains-taking, liberal, and en-

during, is reflected in the pages of his book ; and I may safely aver, from my own having coincided, a few years later, with a part of his North-western route, that his descriptions are accurate, and his conclusions, both on natural phenomena and on the social state of the people, moderate and replete with common sense.

Some critical expressions which fell from M. Tchihatcheff, induced Mr. Hamilton at a later date, in 1849, to recur to the subject, and to present to the Society observations on the geology of Asia Minor, referring more particularly to portions of Galatia, Pontus, and Paphlagonia.

On his return to England he resumed his post as Secretary of the Society, and, notwithstanding his being in Parliament from 1841 to 1847, he continued for many years to act in that capacity, applying to it so much time and attention that he became the chief authority with the Council in all questions that related to the constitution, the bye-laws, and the history of the Society.

Meanwhile a number of descriptive papers issued from his pen :—

In 1844, a long and general treatise on the rocks and minerals of that technically important part of Tuscany which lies between Arezzo and Leghorn, and includes the boracic-acid springs, the copper-mines, and the alabasters of Volterra.

In 1848, an account of the agate-quarries of Oberstein and of the methods of treating the agates artificially for the purpose of changing their colour.

In 1850, on the occurrence of a freshwater bed of marl in the Fens of Cambridgeshire.

For several years he had taken a lively interest in the progress of the long somewhat weakly Geographical Society, and in 1837 was elected to be its President, an honour which he afterwards held during the years 1841, 1842, and 1847.

The most elaborate paper which Mr. Hamilton contributed to our Quarterly Journal was that on the Geology of the Mayence Basin, read in 1854. This detailed description of the remarkable alternations of marine and freshwater Tertiaries extending more or less from Wiesbaden by Mayence to Dürkheim is followed by theoretical considerations explanatory of the changes which have introduced and then checked the growth of a marine fauna in the midst of the Continent. And the character of some of the mollusca straightway suggested to the author that during the Middle Tertiary period a depression of such a nature must have taken place as to open a communication between this region and the Mediterranean, to be afterwards closed again, probably at the time when a movement of elevation succeeded to the great and long-continued depression which had permitted the accumulation of thousands of feet in thickness of marine strata in North Switzerland.

In the same year Mr. Hamilton was elected President of the Society, on the occasion of Edward Forbes being called away from London to take the Professorship at Edinburgh. A short residence on the Rhine had made the new President acquainted with Fridolin Sandberger and others of the West-German geologists, and with the

subjects of their studies; and in the ensuing year he followed up his Mayence paper by another, on the " Tertiary Formations of the North of Germany," with especial reference to those of Hesse Cassel and its neighbourhood, together with, somewhat later, observations accompanying a notice of Professor Beyrich, on the position of the " Brown Coals of North Germany."

In the same year, 1855, he accepted the office of Juror at the International Exhibition of Paris, offered him by virtue of his position as President of the Society; and as I was appointed joint Juror for the same department, we passed some weeks in examining together the various mineral and geological contributions brought together at that great gathering. It was on this occasion that I had for the first time the opportunity of becoming acquainted with our late President's many sterling qualities; and, thrown together with him day after day into positions which called for much exercise of kindly feeling, and for a knowledge of divers languages, amid discussions in which French, German, and Italian came into play, I found it most satisfactory to be associated with a man of so catholic a spirit and so complete a knowledge of the diverse nationalities which were there brought into contact.

His two successive Anniversary Addresses were also examples of the conscientious labour with which he applied himself to the interests of the Society; for he had carefully read and condensed almost every paper and book which had been published on geological subjects during the term of his Presidency.

During the latter portion of his career Mr. Hamilton occupied himself much with Indian affairs, and served as Director and as Chairman of the Board of the Great Indian Peninsula Railway Company from 1849 to 1867. In scientific matters he was interested especially in the Tertiary deposits, and, with a view of furthering his studies in that direction, entered with great zeal into recent conchology. He also paid a lengthened visit to the Channel Islands, and collected an extensive suite of rock-specimens; but, although he had prepared ample notes, he never, I believe, published on the subject.

In several successive years Mr. Hamilton took part in excursions made by several Fellows of the Society, generally under the guidance of Mr. Prestwich, to parts of France and Belgium. And it would surprise those who, as strangers, complained that his manner was cold, to find that no one contributed more than our late President, by his unselfishness and unflagging good humour, to the success of these Easter expeditions.

Soon after his election to the Presidency of our Society, in 1865, it became evident that Mr. Hamilton, although a man of athletic frame, and one who had hitherto looked younger than his years, was suffering from an internal complaint which greatly reduced his powers. He visited the German baths, and passed some months in Italy; but, although for a time he appeared to improve in health, the insidious disease was advancing upon him. He was able, in tolerable strength and good spirits, to give his Anniversary Address and to resign his Presidency in 1866, but was sadly weakened when

he returned to England about a twelvemonth afterwards; and yet it was very unexpectedly that his many friends received the sad tidings of his premature decease.

Although the EARL OF ROSSE was not so thoroughly a geologist as to frequent our meetings, the demise of that eminent leader in the scientific world reminds us that we have lost, not only a sincere friend to science at large, but a Fellow of our own Society of thirty-five years standing. He was born at York, the 17th June, 1800; but his family having long been settled in Ireland, his education was carried on in part at Trinity College, Dublin, and a great portion of his life was devoted to the fulfilment of the duties of a wise and generous-hearted resident landlord among his tenantry at Parsons-town. At an early age (very soon, indeed, after taking a first-class in mathematics at Oxford) he entered life as representative of the King's County, and in 1845 took his seat in the House of Lords; but he is far better known for the zeal and assiduity which he bestowed on mechanics and astronomy, out of which arose the famous reflecting telescope on a scale before unattempted, and a long list of honours conferred on him by home and foreign scientific bodies. For several years he occupied, with general approbation, the distinguished position of President of the Royal Society, and in 1862 he was appointed Chancellor of the University of Dublin. The only comfort left, on the loss of a man so beloved in private life, and so useful as a bright example in his country, lies in the fact that he is followed by a successor whose tastes are also of that intellectual kind which adorn and fortify a high position.

By the decease of Dr. DAUBENY * the University of Oxford has lost the one resident who, by his early social intimacies and incessant labours in science, kept alive the memory and prolonged the influence of the age of Conybeare, Buckland, and Duncan. Freed from most of the anxieties of life, animated by a perpetual desire to advance knowledge, guided by a fine literary taste, and placed in a position of honour and influence, few men have better employed these advantages in college arrangements, University business, or public proceedings in favour of literature and science. The labours of fifty years have been fitly closed in the quiet of his own home, under the shadow of the walls which first received him as a student, in the midst of the beautiful garden which he had enriched and enlarged, and surrounded by friends whose grief in losing him must be the greater the longer was their knowledge of him.

Charles Giles Bridle Daubeny, who was born Feb. 11, 1795, at Stratton, in Gloucestershire, was the third son of the Rev. James Daubeny. He entered Winchester School in 1808, and was elected to a demyship in Magdalen College, Oxford, in 1810. In 1814 he took his degree of B.A. in the Second Class; in 1815 he won the Latin Essay, and then proceeded to London and Edinburgh as a

* For the biography of Dr. Daubeny the President was indebted to Prof. J. Phillips, F.R.S., of Oxford.

medical student (1815–1818). The lectures of Prof. Jameson in Edinburgh attracted his earnest attention, and strengthened that desire to cultivate natural science which had been awakened by the teaching of Dr. Kidd, in the dark chambers under the Ashmolean Museum. The fight was then raging in Edinburgh between Huttonians and Wernerians; and the possession of Arthur's Seat and Salisbury Craig was sternly debated by the rival sects. Daubeny, after quitting the University of Edinburgh, proceeded (in 1819) on a leisurely tour through France, and sent to Prof. Jameson from Auvergne the earliest * notices which had appeared in England of that remarkable volcanic region. Some of the views afterwards advanced by the young physicist touching the geological age of the valleys of Auvergne† have been examined by later writers—Scrope, Murchison, Lyell; while the prehistoric antiquity of the volcanos themselves has been questioned even within a few years, and defended by none more effectually than by Dr. Daubeny‡. From the beginning to the end of his scientific career, volcanic phenomena occupied the attention of Dr. Daubeny; and he strove by frequent journeys abroad—through Hungary and Transylvania, Italy, Sicily, France and Germany—to extend his knowledge of that interesting subject. In 1823–1825 he had by this means prepared the basis of his great work on Volcanos, which appeared in 1826, and contained careful descriptions of all the regions known to be visited by igneous eruptions, and a consistent hypothesis of the cause of thermic disturbance, in accordance with the views of Gay-Lussac and Davy. Water, admitted to the uncombined bases of the earths and alkalis existing below the oxidized crust of the globe, was shown to be an efficient cause of local high temperature, and a real antecedent to the earthquake movements, the flowing lava, and the expelled gas and steam. In later years Dr. Daubeny freely admitted, as at least very probable, a high interior temperature of the earth; but he did not allow that the admission of water to a heated interior oxidized mass would account for the chemical effects which accompany and follow an eruption§. On this point we have still data to be gathered and inferences to be examined.

Four years previous to the publication of the ' Description of Volcanos,' Dr. Daubeny was appointed to succeed Dr. Kidd as Professor of Chemistry, and took up his abode in, or rather below, the time-honoured museum founded by Ashmole. In these rather gloomy apartments nearly all the scientific teaching of Oxford had been accomplished since the days of Robert Plot; in them were still collected (in 1855), by gas-light and furnace-fires, the most zealous students of practical chemistry; but now they are filled with Greek sculpture; and chemistry has flitted to the magnificent laboratories of the University Museum, directed by Sir Benjamin

* " Letters on the Volcanos of Auvergne," in Jameson's Edinburgh Journal, vol. iii. p. 359, and vol. iv. pp. 89 & 300, 1820–1821.
† Edinburgh New Phil. Journ. vol. x. p. 201, 1831.
‡ Quarterly Journal of Science, vol. iii. 1866, p. 199.
§ " Memoir on the Thermal Waters of Bath," Brit. Assoc. Report, Trans. Sects. 1864, p. 26.

Brodie. Long before this, however, Dr. Daubeny had been appointed Professor of Botany (1834), and had migrated to the Botanic Garden, founded in 1632 by the Earl of Danby, and there delivered his lectures on chemistry and botany. Here, during many years of incessant activity, he instituted numerous experiments on vegetation under different conditions of soil, on the effects of light on plants and of plants on light, on the distribution of potash and phosphorus in leaves and fruits, examined the conservability of seeds, measured the ozonic element of the atmosphere, and tested the effect of varying proportions of carbonic acid on plants analogous to those of the Coal-measures[*]. In 1831 appeared his sketch of the Atomic Theory. A favourite subject of research with Dr. Daubeny, naturally springing from his volcanic explorations, was the chemical history of mineral waters. The presence of iodine and bromine in some of these formed the subject of a paper in the 'Philosophical Transactions' for 1830; and a Report to the British Association in 1836 included a general survey of mineral and thermal waters. This subject was not neglected in his North American tour (1837–1838), which contains a great number of interesting observations on the character of the country which he traversed, and its educational institutions, where he was heartily welcomed.

Dr. Daubeny communicated to the Geological Society in 1844 the results of a journey undertaken by him with Capt. Widdrington, R.N., F.R.S., to the south-east of Spain, for the purpose of investigating the conditions of occurrence of the phosphorite of Logrosan. He was accustomed to travel on the Continent almost every year, and generally brought back with him notes serving to illustrate some of his favourite subjects.

So soon as the arrangements were made for the location of chemistry in its new abode at Oxford, Dr. Daubeny took the occasion of resigning the Chair of Chemistry, and used all his influence to increase the efficiency of the office and secure the services of the present eminent professor. In his position as a teacher of Botany he took pleasure in drawing attention to the historical aspects of his subject, and specially, as a part of his duty, treated of rural economy both in its literary and in its practical bearing. Hence arose the 'Lectures on Roman Husbandry' (1857), written in a style very creditable to the classical training of his early years, and containing a full account of the most important passages in Latin authors bearing on crops and culture, the treatment of domestic animals, and horticulture. To this is added an interesting catalogue of the plants noticed by Dioscorides, arranged in the modern Natural Orders. This was followed after a few years by a valuable 'Essay on the Trees and Shrubs of the Ancients,' and a 'Catalogue of the Trees and Shrubs indigenous in Greece and Italy' (1865). During a few late winters Dr. Daubeny found it desirable to exchange his residence in Oxford for the milder climate of Torquay. Here his activity of mind was equally manifested by public lectures on the

[*] Miscellaneous Memoirs and Essays, 1867; British Association Reports, 1837–1857.

temperature and other atmospheric conditions of that salubrious resort, and by experiments on ozone and the usual meteorological elements in comparison with another series in Oxford. By this connexion with Devonshire he was induced to join the Association in that county for the advancement of Science, Literature, and Art; and one of his latest public addresses was delivered to that body, as President, in 1865. In his whole career Dr. Daubeny was full of that practical public spirit which delights in cooperation, and feeds upon the hope of benefiting humanity by association of men. When the British Association came into being at York in 1831, Daubeny alone stood for the Universities of England, and, so standing, boldly invited that body to visit Oxford in 1832. *Quæ nisi fecisset,* it is not at all clear that the then growing nestling would ever have reached maturity. In 1856 he became President of the Association, at Cheltenham, in the country of his birth, amidst numerous friends, who caused a medal to be struck in his honour—the only occurrence of this kind in the annals of the Association. The same earnest spirit was manifested in all his academic life. No project of change, no scheme of improvement in University examinations, no modification in the system of his own college ever found him indifferent, prejudiced, or unprepared. On almost every such question his opinion was formed with rare impartiality, and expressed with as rare intrepidity. Firm and gentle, prudent and generous, cheerful and sympathetic, calm amid jarring creeds of contending parties— the influence of such a man on his contemporaries for half a century of active and thoughtful life fully matched the effect of his published works. His latest labour was to gather his ' Miscellaneous Essays' into two very interesting volumes; and then

> " multis ille bonis flebilis occidit,"

at midnight of Thursday, December 12, 1867.

His remains are to be laid in a vault adjoining the walls of Magdalen College Chapel, in accordance with his own expressed wish, " that he might not be separated in death from a society with which he had been connected for the greater part of his life, and to which he was so deeply indebted, not only for the kind countenance and support ever afforded him, but also for supplying him with the means of indulging in a career of life at once so congenial to his taste and the best calculated to render him a useful member of the community."

Among our losses of the past year are some of the very oldest Fellows of the Society, men who, although they appeared but little among us, had played a most useful part in the formation of the first nucleus of friends of geological science.

Among those, Mr. ASHURST MAJENDIE, of Hedingham Castle, in Essex, who died on the 7th October last, at the ripe age of 83, had interested himself up to the last in our pursuits. Somewhat delicate of constitution in early life, he passed some years in the south of Cornwall, and, having the good fortune to be associated with such

men as Davies Gilbert and Dr. Paris, he took an active part in the affairs of the Royal Geological Society of that county, and of the Museum at Penzance. Notes and specimens he collected largely ; but a natural diffidence appears to have prevented his coming forward prominently as an authority on scientific subjects. He contributed only a few very brief papers to the Transactions of that Society, in 1818 :—one on the Coast West of Penzance, and on the Structure of the Scilly Islands ; and another on the Geology of the Lizard district.

In 1832 he was appointed one of the Assistant Poor-Law Commissioners, and, after succeeding to his family property in the year following, devoted himself mainly to the duties of a country gentleman and magistrate. Mr. Majendie, however, never lost his taste for scientific subjects, and was frequently to be seen at our meetings and at those of the Royal Society, whilst nothing gave him greater pleasure than to come with a few of his old-collected specimens in his pocket to visit a friend and discuss with him some of the Cornish minerals.

Mr. Majendie married, in 1831, the eldest daughter of John Griffin, Esq., the sister of Lady Franklin, but left no children.

Sir George Clerk, Bart., of Penicuick, was born in 1787, was educated at Eton, and became an honorary D.C.L. of Oxford. He was called to the Scottish bar in 1809, and, soon afterwards entering Parliament, occupied himself chiefly with political matters, and held the offices successively of Under Secretary for the Home Department, Assistant Secretary to the Treasury, and Vice-President of the Board of Trade. As early as 1812 he joined the Geological Society ; but although an intelligent amateur of our own science as well as of various branches of natural history, he appears never to have taken an active part in the affairs of our Society. He died the 23rd of December, 1867.

Sir Charles Lemon, Bart., of Carclew, in Cornwall, was born in 1784, and throughout his long life, while fulfilling well the duties of his county position, and for a great many years those of a Member of Parliament, offered an excellent example of the salutary influence which may be exercised by a friend and patron of science and the fine arts. He became a Fellow of the Geological Society in 1813, and afterwards took a prominent part in the installation of local associations intended to promote scientific studies. He became President of the Polytechnic Society, which holds its annual meetings at Falmouth ; and his hospitable mansion at Carclew was ever the rallying-point on those occasions for whatever scientific visitors he could induce to penetrate so far to the west. He was also President for some years of the Royal Geological Society of Cornwall ; and when a quarter of a century ago the question of a mining-school for Cornwall was mooted, Sir Charles Lemon was foremost in endeavouring to bring it to a practical issue. But his earnest wishes and his munificent offer of a donation, upon certain

conditions, of £10,000, alike broke down before obstructive prejudices and sectarian jealousy.

Sir Charles married, in 1810, the youngest daughter of the Earl of Ilchester, but leaves no surviving children. Notwithstanding a very serious illness by which he was attacked a few years ago, the deceased Baronet continued to exercise his hospitalities at Carclew, and was able to attend his parish church within two days of his death, which took place on the 11th of February, 1868, in the eighty-fourth year of his age.

Dr. JAMES BLACK, formerly a resident at Manchester, died in April last at Edinburgh, at the age of 79. Whilst in the practice of his profession of medicine in Lancashire, he mingled much with those friends of science who frequented the meetings of the Geological and of the Philosophical Society of Manchester. He became a Fellow of our own Society in 1838, and of the Geological Society of France in 1848. Dr. Black contributed sundry communications to the Manchester societies, some on archæological and others on geological subjects.

One of the most far-travelled of our Fellows was Mr. EVAN HOPKINS, who died last summer at the comparatively early age of 57. Mr. Hopkins was a native of Swansea, and passed his juvenile years in learning various branches of the processes of iron-making at the great establishments of Penydarran, Dowlais, and Rhymney. In 1833 he received an appointment which took him out to South America, to assume for an English company the responsible charge of the gold-works of Marmato, and soon afterwards was entrusted with the chief direction of the silver-mine of Santa Anna, and of all the affairs of the Columbian Mining Association. On returning to England in 1843 he published a work on Geology and Magnetism, containing a variety of extremely original views, illustrated by reference to numerous observations of his own. After a further visit to America, in the course of which he made extensive traverses across the Andes, and effected a survey of the Isthmus of Panama, he read a paper before this Society in March 1850, on the rocks and cleavage of the great South-American chain, supporting his statements by a beautifully drawn section from the Pacific through Bogotá to the plains of the Meta. But the views of the author on the subject of the mutual relations of the rocks were very peculiar, and, although he deserves the credit of having strongly put forward the importance of the phenomena of cleavage at a time when they had attracted the attention of only a limited class, his knowledge of stratigraphical geology was too imperfect to keep up with his native genius and with his industry as a surveyor. He insisted strongly on the universality of a certain direction in the strike of the planes of cleavage, and on a vertical transition from the less to the more highly crystalline rocks; whilst his arguments against the igneous origin of granite entitle him to be placed among the leaders of a new school, who have, however, hitherto been far from agreeing

among themselves on a general explanation of the occurrence of that important rock.

In 1852 Mr. Hopkins proceeded to Australia as the professional adviser of some of the gold-mining companies, and applied advantageously in the new colony the results of his former experience in the treatment of the ores of the precious metal. He communicated to the Society on his return, in 1854, a brief account of his views on the gold-bearing rocks of Victoria. During several years afterwards he was often occupied in visiting home and foreign districts for the purpose of reporting on their mining-capabilities, and for the last two years devoted much time and practical experiment to the subject of demagnetizing iron ships. On this latter subject he suggested novel methods, which he did not live to carry out to completion.

The late Admiral THEOBALD JONES, M.P., was born in 1790, entered the Navy in 1803, and up to the close of the war was constantly occupied in active service in the North Sea and in the Mediterranean. For many years he sat in Parliament for Londonderry, and in his leisure time formed a large and fine collection of fish-remains from the Carboniferous Limestone of Ireland.

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On proceeding to pass under review some of the recent works which have thrown a light on one portion or another of our Science, I would fain commence by a few words on the progress of that department which most readily commands the appreciation of the public, viz. the exploration of the mineral structure of the country, which has been set on foot by every Government of Europe and by that of the United States.

The Geological Survey of the United Kingdom is advancing rapidly, especially in the coal-fields. The maps of the Barnsley district, on the scale of 6 inches to a mile, are nearly completed, and a considerable part of the Lower Coal-measures and Millstone-grit has been surveyed as far as the north end of the coal-field. The survey of the Lancashire coal-field is now complete, and the 6-inch maps are in the hands of the engraver.

Nearly 300 square miles of the Northumberland and Durham coal-field have been surveyed, and the publication of some of the new maps of the area is far advanced.

In other areas, the Silurian and adjoining formations are being mapped in Cumberland and Westmoreland; and in Northamptonshire the survey of the Oolitic rocks is progressing northward. The Eocene formations on both sides of the Thames, and far to the north, have been entirely surveyed, and the maps are being engraved; and the Rhætic or Penarth beds are being added to the previously published maps of the west of England.

Whether the Government be anxious to prove their sense of the practical value of our science, or only to get a certain piece of work more rapidly out of hand, they have taken a measure well calculated

to form a body of sound observers by greatly increasing the staff of the geological survey. The augmentation amounts, in all, to 33 assistant geologists, viz. 21 for England, 6 for Ireland, and 6 for Scotland; whilst the organization has been modified by the appointment of a separate director for Scotland, Mr. Archibald Geikie, Prof. Ramsay and Mr. Jukes retaining, as before, their control over the surveys of England and Ireland respectively.

Under these directors, Messrs. Aveline and Bristow have been appointed " district surveyors " for England, Mr. Du Noyer for Ireland, and Mr. Hull for Scotland.

Out of the total number of fresh posts, only 19 have as yet been filled up, the requirements of the Civil Service examination having kept back some candidates who, in other respects, were well qualified; and as most of the number are necessarily new to the work, it is not to be expected that any great advance in the amount of surveys completed can be looked for until a couple of years, at least, have been allowed for instruction and practice in the field.

In spite of the obstructions opposed to industry in Italy by the excitement and lavish expenditure of the recent political situation, it is consolatory to learn from Florence that arrangements have been made for the establishment, in connexion with the ministry of Agriculture &c., of a Committee for the preparation of a great Geological Map of Italy, with an organization similar to that of the geological commission of Portugal. Sign. Igino Cocchi, whose frequent attendance at our meetings will be remembered by the Society, is charged with its direction, and Messrs. Meneghini, Gastaldi, and Pasini are his colleagues. Several works of interest have lately proceeded from the pen of some of those eminent cultivators of natural science, among which I will only refer to the description of the Ammonites of the Lias by Meneghini, in the ‘Palæontology’ of the Abbé Stoppani, and to the discussion of the Tertiary and superficial deposits of the Upper Val d’Arno and the Val di Chiana, by Cocchi *.

The discovery in these beds, at a place called the Olmo, near Arezzo, of a human skull of great size and peculiar type, attaches to them a high importance in connexion with the antiquity of man. The conclusions of the Italian geologist are sufficiently startling to rouse the attention and call for the corroboration of other observers. The exhumation of the skull, at 15 metres depth, from a lacustrine deposit in a deep railway-cutting was fortunately witnessed by Cocchi and others; and his examination of the neighbourhood leads him to infer that it lay quite at the base of the Postpliocene formation, beneath remains of *Elephas primigenius, Cervus euryceros, Bison priscus*, and other extinct mammals, that it was buried in the mud of a lake which existed at a time when the surface-contour of the country was extremely different from the present, and that, in fine, man existed in the Præglacial period.

Another conclusion of much interest has been arrived at by the

* " L’Uomo fossile nell’ Italia centrale, di Igino Cocchi," Memorie della Soc. Ital. di Scienze naturali. Milano, 1867.

Tuscan geologists with reference to the often debated question of the true history of the celebrated marble of Carrara. For some time past these marble beds have been, in a very hypothetical manner, placed on a parallel with the Lias; but the newer researches appear to prove, 1st, that there exist two successive series of white marbles; 2dly, that the upper range, as greatly developed near Pisa, belongs generally to the Trias; 3rdly, that the lower series, constituting the greater part of the beds of Carrara &c., are covered by slates and by talcose and ampelitic schists, a group represented in the Apuan Alps by the formation of Tano or the true *Verrucano*; 4thly, that the marbles repose in their turn upon crystalline schists (the Verrucano of Savi), which are now considered Præsilurian; and hence, 5thly, that we must revert to the old idea which assigned the marbles of Carrara, Serravezza, &c. to the Palæozoic period.

The admirable work which has been accomplished by the Austrian Government Geological Survey is doubtless well known to most of our associates; and as I have received from my valued and able friend, Chev. Franz von Hauer, a most interesting summary of their recent results, I cannot do better than communicate his report by allowing him to speak for himself, as follows :—

"As far as I am aware, the last information on the progress of our labour, laid before the English public, was in a Report addressed by my predecessor in the management of the Imperial Royal Geological Reichsanstalt—our honoured Haidinger—to the Meeting of the British Association for the Advancement of Science at Birmingham.

" Our survey work has been carried on since that time exclusively in the north-western part of Hungary, the mapping of which is now already completed to the eastern foot of the highest mountain-group of the Carpathians, the central mass of the High Tatra. Very remarkable are the analogies as well as the contrasts offered by this western portion of the Carpathians (between Presburg and the meridian of Kaschau) in comparison with the Alps.

" The several groups, distinctly isolated from one another, of crystalline rocks (granite and crystalline schists) which, distributed very irregularly, come to light throughout the district, involuntarily remind one of the so-called central masses of the western Alps; but the sedimentary rocks which surround and separate them from one another show nothing of the action of that widely developed metamorphism which the rocks of the schistose envelope of the central Alps present to view. Manifold are the discoveries which have been brought out by a close examination of these sedimentary beds. The oldest member of these, as established with any degree of certainty, consists of the schists and limestones of the Culm-formation; yet Foetterle has lately found data which make it probable that a still deeper-lying group of strata, consisting of quartzites, schists, limestones, &c., is to be placed on a parallel with the Silurian Greywacke of the Alps. Widely extended masses of quartzite, frequently in association with Melaphyre, but unfortunately always without organic remains, represent, perhaps, in a measure the Permian or Dyas Formation. Again the Trias is decidedly recognized, deve—

loped in numerous divisions which correspond completely with the beds known to occur in the Alps, and especially with the so-called *Virgloria-kalk* with its Brachiopods of the *Wellenkalk*. Beyond these follow the Rhætic formation, the Lias, Jura, Chalk (the latter especially distinguished by the occurrence of thick masses of dolomite, which, petrographically, are not to be distinguished from the far more ancient Triassic and Rhætic dolomites of the Alps), and at last the Eocene formations.

" A parallel zone of limestone, such as occurs especially so distinctly and largely developed in the eastern portion of the Alps to the north and south of the middle zone, is totally wanting in the Carpathians. The pile of crystalline central masses and the sedimentary rocks enveloping them, and which, as before mentioned, appear to represent the middle zone of the Alps, is followed on the north, immediately, by the broad zone of the long-known Carpathian Sandstones. We have succeeded by our surveys in the Carpathians in resolving this zone of sandstone, far more sharply than in the Alps, into its different divisions, and are enabled not only to separate the Eocene from the Cretaceous sandstones, but also in these latter to distinguish various subdivisions. One of the most remarkable phenomena in the structure of the Carpathians, as is well known, is the peculiarly craggy limestone cliffs towering out of the zone of sandstone (the *Klippenkalk*, as it was called by Pusch), to explain the origin of which the most various hypotheses have been invented. Our investigations have proved that strata of very different antiquity, beginning with the Lias or even with the Trias, and extending upwards to the Neocomian formation, have participated in the composition of these cliffs, and that they exhibit disturbances of the original stratification such as are very seldom to be observed within a similar area. Every one of the numerous cliffs is formed of a great mass of limestone composed of members of different formations, each of which stands in no direct connexion with its neighbours ; indeed it is often the case that several masses with divergent direction of the dip and strike of their beds take part in the composition of one and the same cliff. One of these cliffs (near Podbiel, in the Arva county) shows a complete reversal of the beds ; from the Neocomian *Fleckenmergel*, as the lowest member, there follow in it, in the ascending order, Jura limestones as far as the Lower Lias ; and moreover, in reference to the question which is engrossing in so lively a manner the attention of geologists, concerning the age of the limestone with the *Terebratula diphya* and its allies, and on the boundary beds between the Jura and Chalk, these cliffs provide us with the most important points of comparison. Herr von Mojsisovics has been especially successful in establishing a whole series of groups of beds on a parallel with the *Tithonian étage*, in which, to mention only one of them, the *Stramberg* limestone, at any rate, keeps its place in the Jura formation.

" One of the most remarkable characteristics which distinguish the Carpathians from the Alps is the enormously massive occurrence of trachytic rocks in the former. It is true that our detailed ex-

aminations have not yet reached the two greatest of these features—the range extending north and south from Eperies to Tokay (which cuts off the whole mass of the crystalline and older sedimentary rocks of the southern half of the Carpathians on the east, like a grand fault of dislocation, and yet does not cause any disturbance in the regular course of the sandstones lying on the north), and then, secondly, the still more extensive range from Vihorlát to Gutin (stretching from north-west to south-east, and which is probably continued in the Hargitta of Transylvania). But our labours already include the thick and more boss-shaped masses of the Matra group, of the Ore Mountains of Schemnitz and Kremnitz, and, lastly, of the neighbourhood of Gran. Especially do the Trachytes appear in the latter district abundantly, in contact with newer fossiliferous Tertiary rocks. It is evident that an older portion of these, which probably belongs to the horizon of the Upper Oligocene formation, contains no trace of the débris of the trachytic rocks—that these last, on the other hand, occur frequently in great abundance in the Leitha limestone and the marine Miocene beds of the age of the deposits of the Vienna basin (a proof that the trachytic eruptions of this country at least had their origin in the beginning of the Miocene period). The close of this period of trachytic eruptions occurs at the time of the deposition of the Cerithium-beds.

"The work accomplished by Richthofen, at the time of the first general outline of our survey, with such excellent results, relating to the discrimination and separation of the different branches of the trachyte family, which in great part differ from one another in antiquity, has been since much enlarged and completed, especially by Dr. G. Stache. To the groups of the Rhyolites, first proposed by Richthofen, including the true trachytes and the greenstone-trachytes, Stache has added a further series in the older quartzitic trachytes or 'Dacites.'

"Very interesting results have been obtained by Carl von Hauer and other chemists through their valuable analyses, not only of the rocks in general, but also of the felspars crystallized out in them. The analyses show that in the Hungarian and Transylvanian rocks of the trachyte family, in what relates to the degree of acidification, all the members of the series hitherto known, from the most basic to the most acidic, are represented. In the nature of their felspars, on the other hand, these rocks differ materially from the rocks of all trachytic districts that have hitherto been carefully examined ; they are in fact chiefly basic lime-soda-felspar, wavering between Labradorite and Oligoklase, probably corresponding to what has been called by Abich and others "Andesine." This lime-soda-felspar forms the principal ingredient of the basic Andesite and Greenstone trachytes ; in the more acidic Dacite, Sanidine appears with it ; in the still more acidic Rhyolite, finally, the whole of the felspar appears to consist of nothing else but Sanidine.

"And, though it does not concern the area of our Austrian survey, I would here also allude to the analyses (carried on in our laboratory) of the volcanic rocks brought to the surface by the latest eruption

of Santorin. It results that this eruption brings to light acidic as well as basic rocks—and, indeed, the former in the beginning, and the latter during the later stages of the eruption.

"The renowned ore-bearing localities of the trachyte masses of Schemnitz and Kremnitz have offered us likewise the opportunity for comprehensive study. Whilst Baron von Andrian surveyed the geological phenomena of the country with greater exactness than had hitherto been the case, Bergrath Lipold occupied himself with the lodes themselves and the mining. A detailed monograph, printed in the third number of our Jahrbuch for 1867, gives, along with a geographical and geological review, a comprehensive statement of the history of the Schemnitz mines, and, further, a complete description of all the lodes; which appear partly in Rhyolite (at Königsberg), most abundantly in Greenstone trachyte and Dacite, but partly also in Syenite.

"But beyond those districts in which our detail surveys were at work I have manifold labours to mention, which partly refer to those portions of the country that had been earlier surveyed, and enlarge our knowledge of them, and partly concern some districts that had not yet been examined. The former of these have had a special tendency to break up those great groups of sedimentary rocks which were separately laid down in the maps of our survey, and to correlate them with the subdivisions of the formations determined outside the district of the Alps and Carpathians. In fact these inquiries have given proof that, at least in many cases, a parallel of this sort may be carried much further than had hitherto generally been believed.

"With regard to the Alp-country I may here refer to the important observations furnished by D. Stur[*] 'On the Occurrence of Silurian Fossils at the Erzberg, near Eisenerz, in Styria,' which gives not only a very welcome further proof of the Silurian age of the Greywacke zone of the Northern Alps, but also allows us to assume the presence of several successive zones in this formation,—

"Also to the observations of Peters and Klav 'On the Devonian Formation of the neighbourhood of Gratz'[†], from which it appears that in all probability the three divisions (the Lower, the Middle, and the Upper Devonian) are represented,—

"And to the labours of Suess and Mojsisovics on the Trias, Rhætic, and Lias formations in the Salzkammergut[‡], which attempt a highly detailed arrangement of these formations, and, as an example, show the Lias zone of the *Ammonites planorbis* and the *A. angulatus*, &c., in a manner completely agreeing with occurrences beyond the Alps. Some of these views are opposed by Mr. D. Stur[§]; whilst, on the other hand, the accepted division of the Rhætic beds has received satisfactory confirmation in the researches carried out by Dr. Schlönbach in the neighbourhood of Kössen[||].

* Jahrb. d. geol. Reichsanstalt, 1865, p. 267, Verh. p. 261; 1866, Verh. p. 58.
† *Ibid.* 1867, Verh. p. 25.   ‡ *Ibid.* 1866, Verh. p. 158.
§ *Ibid.* 1866, Verh. p. 175. || *Ibid.* 1867, Verh. p. 211.

" Of not less importance to our knowledge of the Upper Trias beds of the Alps is the work of Prof. Suess on Raibl, which is printed in the last number of our Jahrbuch.

" Allow me to specify, with regard to the Alpine country, the geological survey map of the Duchy of Styria by Dionys Stur, which brings into play not less than seventy-seven different tints and indications for the distinction of separate members of the formation and different kinds of rock.

" For another highly important work concerning also the Alpine and Carpathian countries we have to thank Mr. D. Stur,—' Contributions to our knowledge of the flora of the freshwater quartzites of the Congeria- and Cerithium-beds in the Vienna and Hungarian basins '*, in which the flora of not less than forty-nine different localities, with 233 species, is thoroughly described, and, with the help of these remains, the geological age of every locality is established. It is especially of far-reaching interest that a series of these localities fills up the gap which exists in Switzerland between the Oeningen formation and the glacial shaly beds of Utznach and Dürnten.

" And, besides the flora, we receive also important contributions to the increase of our knowledge of the fauna of the newer Tertiary deposits. The recently published seventeenth and eighteenth numbers of the great work by Dr. M. Hörnes, published by the Imperial Geological Survey, on the fossil Mollusca of the Tertiary basin of Vienna, are the last but one of the whole work, of which the last will follow in the course of the present year. On the other hand, for a truly splendid collection of the mammals from the brown coal of Eibiswald we have to thank Mr. F. Melling. On this collection Mr. E. Suess has given a preliminary notice †, and it is well fitted to enlarge our knowledge of the higher classes of animals.

" In the past year appeared also the geological map of Moravia and Silesia, the work of Franz Foetterle, in two sheets, printed in colours with forty-two different tints.

" Yet one further discovery I must report in the Carpathian country, made by Mr. Fr. Herbich,—the beds of Bucsecs, near Cronstadt, and at Balan on the eastern frontier of Transylvania, rich in splendidly preserved fossils belonging to various stages of the Jura formation. On these Suess and I ‡ gave a Report; and it results that in them several of the zones of the western countries of Europe are recognizable.

" Of great scientific as well as economic interest are the accurate studies which Mr. Posepny has just published on the Salt-districts of Transylvania §. This work, illustrated by numerous sketches and maps and sections, will receive the greater recognition, inasmuch as since the works of Fichtel very little has been made known on this subject.

" The conclusion of an important part of our labours will finally be

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* *Ibid*, 1867, p. 77.   † *Ibid*. 1867, Verh. p. 6.
‡ *Ibid*. 1865, Verh. p. 255; 1866, Verh. p. 191; 1867, Verh. pp. 28, 126.
§ *Ibid*. 1867, p. 475.

effected by a general map of the Austrian monarchy, which I am preparing from our Government Geological Surveys. It will be in twelve sheets, of which one (No. 5), containing the western Alpine districts, appeared last year, whilst a second, the eastern Alpine country, will be ready to send out in a few weeks.

" I have done myself the pleasure of sending to you, and also to the Geological Society, copies of the first sheet."

Geology of the Western United States.—For many years past we have had to welcome, from time to time, the appearance of the official Surveys and Reports which have been executed at the charge of the several States of the American Union, by geologists of high reputation and untiring perseverance. The two handsome volumes recently published under the authority of the legislature of Illinois present us with the results of the labours, commenced early in 1858, of Mr. A. H. Worthen and his assistants, Prof. Whitney, Prof. Lesquereux, and Mr. Henry Engelmann, in the examination and description of a tract 378 miles long by 210 at its extreme width, included within the limits of the State of Illinois. It is to be hoped that a third volume, the materials of which are already collected, will ere long appear, an equally good specimen of paper and typography, in spite of a certain party opposition which has delayed the publication of matter perhaps even more useful to residents than to the friends of science at a distance. We had in some measure been prepared by the earlier surveys of other of the Western States for the comparatively monotonous and uneventful geological structure of these extensive tracts ; but the very simplicity of the features confers an importance of a social kind on the broad prairies, the gently undulating coal-field, and the slightly elevated hills of the lead-bearing limestones, all now being rapidly inundated by the advancing tide of population.

The course of the river-valleys is occupied by beds of the fine freshwater quaternary deposit which the American geologists have agreed to term *loess,* measuring from 20 to 60 feet thick in the river-banks and thinning out up the country, and testifying to the former presence of a chain of lakes. Above this is found, through a large portion of the district, a detritus formed of materials many of which, as fragments of the red sandstone and native copper of Lake Superior, have evidently been swept southwards from their native beds, whilst the underlying limestones, when the gravels rest immediately on the rock, offer in their polished and grooved surfaces distinct evidence of long-continued glacial action. A singular exception is the slightly elevated plateau of some fifty miles in length, trending east and west, on the south side of the Wisconsin river, where a total absence of the foreign drift, so abundant elsewhere, and even on the higher ground, marks the productive lead-bearing region which extends from this State into Iowa and south-western Wisconsin.

Tertiary strata of but small importance are shown to exist in the southern part of the State, especially in Pulaski county, whilst the whole of the Mesozoic or Secondary formations appear to be absent, and the alleged Permian rocks, containing fossils very similar to

those which had been called lower Permian in Kansas by Prof. Swallow, are considered by the State surveyors to be a series of strata in no way separable from the great western coal-fields.

Much uncertainty has prevailed respecting the true value of the coal-measures, which cover more than two-thirds of the surface of the entire State; and it is by no means dispelled by the information published in the Report; for without a great additional number of actual trials, it is impossible, in a region where there are so few accidents of stratification to bring the beds to the surface, to predicate the continuity or workable character of the seams. Where fully developed, in the southern part of the State and even as far north as Fulton and Peoria counties, the measures contain, it is stated, at least five or six workable beds of coal having an aggregate thickness of nearly twenty feet. Dr. D. D. Owen published a section for Shawneetown, numbering twelve seams, with a total thickness of 35 feet, in 860 feet of strata, included between the base of the so-called Anvil-rock and the top of the conglomerate or Millstone-grit. The lower seams, however, are restricted to the southern part of the field, the upper ones only extending to the northern confines, whence it would appear that during the period of the deposition of the coal there must have been a gradual subsidence of the entire surface of the Illinois coal-field.

Prof. Worthen ascribes the uneven surface upon which the coal-measures have been deposited, to the thinning out of the strata as they pass northwards, and to the erosion of the valleys down to the subjacent limestones,—those appearances of irregularity which have been exaggerated and explained, by Dr. Stevens, Dr. Norwood, and others, as a division or breaking up into small coal-basins by upheavals and dislocation.

On the extreme north-eastern border of the coal-field, the measures contain but a single bed of coal, averaging about three feet in thickness, but of unusual importance from its accessibility at moderate depth and from its proximity to that great centre of activity, Chicago. An interesting feature exhibited by the sections consists in the frequent repetition of bands of calcareous shale or of limestone abounding in marine fossils, and of which the Director states that "there is probably not one of our principal coal-seams that has not, at some locality in the State, a bed of calcareous shale or a limestone associated with it containing the fossilized remains of marine animals." The importance of these facts in a review of the dynamics of the formation of the Carboniferous strata, and their parallelism to those of our own Scottish fields, needs not to be enlarged upon.

Below the coal-measures there occurs a series of "subcarboniferous" limestones divided into several groups, known by local names, and which, whilst they have an aggregate thickness of 1500 feet in the southern portion of the State, thin out on the north and disappear entirely on the western borders of the coal-field. At the base of the division called the Burlington limestone, well known to palæontologists for the beauty and variety of the Crinoidea occurring at its northern outcrop, follows a series of beds, chiefly gritstones

and shales, called by the surveyors the Kinderhook group, and decidedly held to be the lowermost division of the subcarboniferous formation, although ascribed by Prof. Hall to the Devonian. The occurrence of these beds as the commencement of the Carboniferous system gives rise to a theoretical view which, although indorsed by our eminent associate Dr. Dawson, I cannot but regard as overstrained if it be applied to the several systems of strata as at present classified. "We have," says Prof. Worthen, "at the base a fragmentary series composed of sandstones and shales, the *débris* of pre-existing formations, in the middle calcareous and highly fossiliferous beds, representing the higher divisions of the subcarboniferous series, and ending in the ascending scale with another fragmentary series, comprising the sandstones and shales of the coal-measures." No doubt, however, as Dr. Dawson observes, "this recurrence of cycles deserves a more careful study as a means of settling the sequence of oscillations of land and water in connexion with the succession of life."

The Devonian strata occur in three divisions of very moderate thickness, but are underlain by massive limestones of the Upper and Lower Silurian epoch, which are no less important for the physical character they confer on the northern portion of the State, than for the astonishing quantity of lead-ore produced from them within a few years. Prof. Whitney, favourably known for a number of works on analogous subjects, has contributed a detailed Report on these Silurian limestones and their contents, which, from his former experience in Iowa and Wisconsin, he was specially fitted to prepare. The siliceous strata which form the base of the system, the equivalents of the Potsdam sandstone of New York, never rise to the surface in Illinois; but the next group above, the lower Magnesian limestones, on the level of the "Calciferous Sandstone" of the New-York Report, make their appearance in an arch or undulation of the strata at La Salle. Over these follows a series, for about 150 feet in thickness, of alternating calcareous and siliceous bands, and then the important aggregate of beds called the Galena limestone, 250 to 275 feet thick, mostly a typical dolomite, yellowish grey in colour, and weathering in fantastic forms, which confer a picturesque charm on the narrow valley opening to the Mississippi. Its fossils, which are abundant, place it, together with the relatively thin underlying bed termed the "blue limestone," on a parallel with the Trenton group as described by Prof. James Hall.

A band consisting chiefly of shales, the "Cincinnati group," of no great thickness, separates the "Galena" from the "Niagara" limestone—again a powerful mass of dolomite, very similar in its lithological character to the galena-zone, but so different in fossil contents as to have been termed, even before the advent of the Survey, the "Coralline and Pentamerus beds." Singularly destitute of any trace of the mineral treasures which are scattered so lavishly in the lower dolomite, this thick bank of rock plays otherwise a very prominent part in the physical geography of a large portion of the Western United States, forming the highest points in Illinois and

then stretching away into Minnesota and the immense expanse of
the far North-west.

Although the first settlers took up their abode in this remote region
as early as 1821, the mineral treasures cropping up to the surface
of the ground began to be worked only in 1827, when the name
Galena (from the well-known ore of lead) was given to the town,
which soon became the emporium of the lead-trade of the Upper
Mississippi.   By the years 1840 to 1845 it had increased so largely,
representing at the maximum a production of about 25,000 tons a
year, as to exercise a powerful influence on the metal-markets of the
world.   The description of the localities now laid before us offers
some explanation of the rapid exhaustion of deposits which used in
vague language to be termed mountains of lead.

The veins or " crevices," as they are termed, thus confined to the
Galena limestone are found in great numbers, but never continuous
for more than a few hundred feet in length, scattered in patches
over a wide extent of territory, the productive ones ranging in an
east and west direction, and others of less value, but sometimes ore-
bearing, crossing that direction nearly at right-angles.   Their appear-
ance in fact induces Prof. Whitney to infer, with much probability,
that the origin is due to the same causes that have produced " joints "
in almost " every variety of rock occurring in large homogeneous
masses, and especially where a decided crystalline structure exists
in them."   But the workings are rarely more than 80 or 100 feet
deep (in one or two instances, near Dubuque, nearly 180 feet), and
it seems that no trace of the metallic contents can be found below
the beds of the " Blue limestone," nor upwards in the " Niagara sys-
tem."   It is argued hence, with some boldness, that, the metal lead
having been held in solution in the oceanic waters from which the
rocks of the north-west were thrown down, the metalliferous combi-
nations were decomposed by the organic matter of these limestone-
beds, among which the ores are now found to occur; and thus it
would seem to be inferred that the " crevices " were formed, and
were partly filled with the galena and its accompaniments of zinc-
blende, and fluor-spar, before the formation was covered up by the
deposition of the shales of the Niagara group.   In curious juxta-
position with the metallic minerals which have contributed so much
to the peopling and investigation of the country, are found bones and
teeth of both extinct and living species of land animals, confusedly
mingled in the vein-fissures down to depths of 50 or 60 feet.   The
most abundant are remains of Mastodon, which, from the quantities
found in different veins extending through the whole district, seem
to show that the species must have flourished in vast numbers and
through a long period of time.   In one crevice, near Dubuque, Prof.
Whitney obtained, with bones and teeth of the Megalonyx, teeth of
a Peccary, pronounced by Wyman to be those of a species now living.
These curious facts remind us of the remarkable discovery made by
Mr. Moore, of Liassic and Oolitic fossils in the lead-bearing veins of the
Mountain-limestone of the Mendip hills, with the difference that in
the latter case there is no doubt that the region of the fissures was

long depressed under the sea, whilst the ancient limestones of Illinois bear no evidence of any superior deposit having covered them, and exhibit only the results of long-continued atmospheric action. The authors of the Report, indeed, hold that this part of the country has not been under water since the deposition of the Upper Silurian rocks.

Numerous details of great value for the comprehension of local conditions are given in the special Reports on particular Counties prepared by different members of the Survey; and an interesting discourse on the origin of the Prairies, by Prof. Leo Lesquereux, states the opinions of other authors on the subject, and gives his own view of their formation by changes in the direction of the drainage of the country, as illustrated especially by the now advancing transformation of the Bay of Sandusky.

The second volume is occupied by a series of Reports on the Palæontology of the district, in which Prof. Worthen has been aided by Messrs. Newberry and Meek for the Vertebrates and Invertebrates respectively, whilst a new Batrachian from the Coal-measures is described by Prof. Cope, and a number of new Polyzoa by Dr. Prout. The fossil plants are figured and described by Prof. Lesquereux, and the numerous plates do great credit to the work of the Western Engraving Company of Chicago.

Before proceeding to notice new works in special walks of our science, I must in a few words advert to two books of a more general and wide scope, in which we may feel almost a personal interest.

It is a great satisfaction to one like myself, brought up from boyhood to appreciate the unwearied exertion and the logical reasoning which have rendered famous the name of Lyell, to be able to announce the completion of the tenth edition of the 'Principles of Geology.' The first volume appeared last year; and so much has it been enriched by matter gathered together during the past thirteen years, that all those students of nature who have enjoyed the multifarious additions to the earlier portion of Sir Charles's treatise, will be impatient to see the second volume, which is not yet issued by the publisher*.

In the same year has been issued the new edition of 'Siluria,' on which we may congratulate our veteran leader Sir Roderick Murchison, not only that his domain appears to be constantly extending into new regions, but that the book itself has been amplified and revised with an amount of labour testifying to his unimpaired mental and bodily vigour. All geologists will be aware that considerable changes have been needed within the last half a dozen years in consequence of the discoveries of Sir W. Logan in Canada, of the works of Barrande in Bohemia, Harkness in Cumberland and Westmoreland, of the determination of the New-Red-Sandstone reptiles by Huxley, and, last though not least in the estimation of the outer world, by reason of the facts promulgated concerning gold, which have led to the modification of views put forth in the older editions. And still, as before, all who are desirous of examining our own more

' *[The second volume has been published since the reading of this Address.— Edit.]

ancient districts, or of investigating analogous formations in foreign lands, will turn to ' Siluria ' as a friend and guide.

Physical Structure of Palestine.—An idea has obtained footing, even in well-informed circles, that the geological structure of the Holy Land is almost entirely unknown ; and our presumed ignorance has been cited as one of the special reasons for promoting the proposed exploration of Palestine. The partial knowledge which we possess may, it is true, stimulate a desire for more ; and the numerous subjects of interest which exist in those regions demand a more thorough attention than has yet been accorded to them ; but we must not forget the important contributions, some of them a quarter of a century old, of Dubois de Montpéreux, of Russegger, Anderson, Lartet, and others, to which has recently been added an unpretending but very readable volume by Prof. Oscar Fraas, of Stuttgart *. Happily breaking away from the fetters imposed by the halting fragmentary entries of a journal, the author starts from the crystalline nucleus of the Sinai peninsula, and describes with the fervour of a northern, to whom such sights are new, the naked charms of its bright minerals and particoloured rocks, free from the encumbrance of soil and of vegetation. The home of the turquoise, worked for some years past by Major Macdonald, he describes as being in the cracks of the porphyries of the Megarah valley, where that valued gem is associated with oxides of iron, especially of those kinds termed bean ore and pisolitic ore, and would appear to have been deposited by the same agencies. In the same (*i. e.* the northern) district of the Serbâl, as well as in the central group of the Hebrân and el Schech, the peculiar weathering of the granite is very observable, not only as producing the most strange and fantastic forms, but as appearing to proceed from the centre of the blocks towards the circumference, and thus giving rise to rounded hollows which, somewhat enlarged and modified by art, have served as the abodes of troglodyte hermits in the early ages of Christianity. As the traveller passes over the totally arid surfaces of granite, syenite, and porphyry, if there be seen, in valley or on mountain-side, the bright green of an oasis, or if water makes itself visible rising from the rocky fissures, it is almost invariably where a portion of gneiss or mica-schist will be found in close proximity, and where it has forced the liquid to the surface, doubtless, by its foliated structure and greater freedom from vertical planes of division.

The mingled syenites, granites, and porphyries of Sinai form a striking feature of the geological map published many years ago by Russegger ; but although these, with various other igneous rocks, are shown to correspond with large masses of the same order in the African deserts bordering the Gulf of Suez, and again with a number of smaller protrusions in a line running northward towards the Dead Sea, there is a great lack of further definite information. Dr. Fraas gives a picture of the frequency with which greenstone dykes cut through the granite : on making the ascent of the Serbâl, he

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* Aus dem Orient. Geologische Beobachtungen am Nil, auf der Sinai-Halbinsel und in Syrien, von Dr. Oscar Fraas. Stuttgart, 1867.

found his party mounted at length on one among forty-seven sharp peaks, within a space of perhaps a thousand metres, and observed that each peak was formed by a dyke of diorite which, with its tough material and angular structure, had resisted the action of the weather in a far higher degree than the granite. In the group of Mount Horeb (Jebel el Tur) and its central pillar (Jebel Musa) the same varieties of crystalline rock occur, but on a larger scale, the aphanitic greenstones being no longer in dykes of a few feet in width, but in vast masses; and a different and more majestic character is thus imparted to the mountain, which induces Dr. Fraas, although leaning to the opinion of Lepsius that the Serbâl is probably the true historical Sinai, to acknowledge the force of the claim urged by the Greek monks for the superior sanctity of the Mountain of Moses.

The mounds of fragmentary matter, 40 or 50 feet high, which sometimes bar up transversely, and in other cases are heaped along the sides of the valleys, have been commented upon by former visitors; but we now have them, for the first time, I believe, confidently referred to the action of glaciers. The materials of the detritus in the Wadi Hebrân, and in the valley of Feirân, blocks and stones of all sizes, from 1000 cubic yards to mere sand and gravel, tumultuously tumbled together, are pointed to as being aggregated in such a manner as no other imaginable agency could aggregate them; and the walls of rubbish, through which the modern winter-streams have cut narrow channels, are piled across the principal or the secondary valleys precisely in the manner of terminal and lateral moraines. Not that the Stuttgart professor deems it needful to refer these phenomena to the Glacial period of Europe; he sees in the southern part of the peninsula no trace of Tertiary or Secondary deposits, and thence assumes that Sinai has been dry land from the earliest periods, and that "these glaciers may as well date from the Silurian period as from that of the Jura, or from the Tertiary."

Another suggestion of startling novelty is that put forward in explanation of the peculiar form of the *wadis*. These arid and rockbound valleys, partially occupied by a rush of water after the wintry rains, present on the west a narrow entrance which the traveller coming from Egypt, until he actually enters them, makes out with difficulty, from the lofty cliffs through which they are opened.

Further and further in, as you advance towards the nucleus of the higher mountains, the wadi opens out wider and wider, without any such change being noticeable in the rock as might have led to its easier disintegration; and at length, at its head, it becomes a broad flat valley, in which you can with difficulty mark the exact line whence the waters would flow in an opposite direction, but where it is to be observed that, instead of contracting again as on the west, it opens out to a still broader wadi, debouching at length from the high ground. These features would be explained, our author believes, on the supposition that the levels of the country have been greatly changed in comparatively recent times, and that, before the opening of the Red Sea, the Sinaitic group and the old *Mons porphyrites* of Egypt were so connected that

the water flowing from the latter would take its way across the area of the present Gulf of Suez, then through the narrow defiles at the commencement of the Wadi Feirân, Hebrân, and others, and so away to the north and east, eroding the valleys into the forms which they now present.

The vast development of limestones which lends a special character to a great portion of Palestine has been generally ascribed, by earlier geologists, to the presence of a great series of strata of the Jurassic or Oolitic period, capped here and there by beds of white chalk ; and Russegger and the United States explorers have expressed themselves very decidedly in favour of this view. But the proofs brought forward have always been of the weakest. Those rugged steps of bare stone, up and down which wind the tracks serving in Judæa for roads, are bold outcrops of successive beds of limestone, often hard and dense, and even marbly in character ; but in the examination of the rocks between Jaffa and Jerusalem the few fossils found, through a series of beds making up 1600 feet in thickness, all belonged to the zone of *Ammonites Rhotomagensis**. The band of easily worked stone (the *mélekeh* of the Arabs), which, with its caves and sepulchres, and its quarries worked far under the city, forms one of the most interesting features about Jerusalem, contains not a single Jurassic fossil, but consists, in great part, of remains of *Hippurites Syriacus*, Conr. Itself about 30 feet thick, it is, at 30 feet interval, overlain by another very regular bank of a harder stone (the *missih* of the Arabs), from which the enormous blocks still seen in an angle of the city wall were taken, and containing numerous fossils, especially Nerineæ, with Hippurites, and a Radiolite, probably *R. Mortoni*. Further than this, in the hard *missih* marble were found, to the author's great surprise, numerous examples of a Nummulite, on seeing which he naturally thought at first of *Cyclostega* or *Cyclolina*, but about which he felt confident on closer examination of its spiral convolutions, and now describes at some length under the name of *Nummulites cretacea*. The statement would be unsatisfactory but for the circumstance that the explorer took the specimens himself from the rock in the Wadi Jôs, where he saw overlying it other beds containing Hippurites and Ammonites ; and hence he is satisfied that one species at least of Nummulite lived in the Cretaceous seas. The higher strata in the neighbourhood of Jerusalem are the soft chalky limestone seen on the Mount of Olives, and corresponding with the Greensand, containing Ammonites of the species *A. varians*, *Mantelli*, &c. The presence of loose flints enclosing *Nummulites variolaria*, Sow., tells of the removal by denudation of upper beds which are seen further east, where the flints form regular bands in a light-coloured chalk, and where, as M. Louis Lartet has pointed out†, the upper chalk beds pass insensibly into the Tertiary, the stratification and lithological character remaining identical, whilst Dr. Fraas holds that the fossils in the upper part of the section imply a transi-

* [Dr. Duncan determined the Middle Cretaceous age of the rocks of Sinai in 1866. See Quart. Journ. Geol. Soc. vol. xxiii. p. 38.—Edit.]

† Bull. de la Soc. Géol. de France, tom. xxii. 1865.

tion between the Cretaceous and the Eocene strata, the Nummulite representing the older Tertiary, and *Ostrea vesicularis* as certainly belonging to the chalk. Not even in the deep and rugged defile of the Cedron are strata of any older formation laid bare : the rock-hewn cells and chambers of the monastery of Marsába are hollowed out of the same soft Hippurite-limestone which has served for the cata- combs at Jerusalem ; and it is only some miles further towards the east that, where the valley begins to open out, grey sandy marls, alternating with black bituminous limestones containing numerous Baculites, represent the middle " greensand" of Western Europe. As for the great chasm of the Dead Sea and the lower valley of the Jordan, not only does the latest geological visitor record the entire absence of any products that can be ascribed to volcanic action, but he avers his conviction that it is simply the result of erosion out of a range of strata of almost perfect horizontality. The period of the opening out of this huge depression is put back beyond the Tertiary, because no deposits of that time are met with between the Lebanon and Egypt, and it would seem that Palestine had never been sunk beneath the sea since the end of the Cretaceous epoch.

That the Dead Sea for a long time occupied a level of more than 300 feet higher than at present, and that its waters must thus have extended far up towards the lake of Tiberias, is evident from several circumstances ; but even the days of that higher water-level must have been very long ago, and it is quite out of the question to admit that any great feature of the phenomena, such as the rend- ing of the valley, or the change of the character of the water, could have been effected by volcanic agency within the historical period.

The wearisome monotony of the evenly-bedded Cretaceous strata of Judæa extends into Samaria and Galilee ; but the interruption of the plain of Jezreel brings at last a refreshing change, where the richer red soil, and the loose masses of black stone cropping to the surface, tell, even at a distance, of the vast basaltic flows which seem to start from the lesser Hermon, to occupy broad tracts of the country up to Tiberias, and then, beyond the lake, to stretch far away into the distant Hauran.

In most of his main views of the stratigraphical structure of Palestine, Dr. Fraas agrees with M. Louis Lartet, who had already, in 1865, exposed the absence of proof for the existence of rocks older than the Cretaceous period[*]; but this promising young geo- logist had the advantage of penetrating, with the Duc de Luynes, the hill-country of the eastern side of the Dead Sea, and thus ma- king the first geological observations on a tract which the peculiar habits of the Semitic race render it so difficult to traverse. Thus he was enabled, at the base of the Arabian chain, in a north and south direction, from the middle of the Jordan valley down to Mount Hor, to find outcrops of a ferruginous sandstone which he considers to be the lowest bed visible in the whole country, still Cretaceous, and probably the same which, in the north, has yielded the lignites of Lebanon, and on the south is so noticeable in the dark-red rocks of

[*] Bull. de la Soc. Géol. de France, 1865.

Petra and the almost equally celebrated sandstones of Nubia. In the two latter regions they are associated with conglomerates ; but, whilst the relative antiquity of the whole of this thick series bears importantly on many of the most interesting questions respecting the conformation of this corner of Asia and the neighbouring part of Africa, the almost total absence of fossils has hitherto left their identification very uncertain. By a singular chance, I am enabled apparently to verify the statement of M. Lartêt, that these beds belong to the Cretaceous period. Some few months ago, our late associate Mr. Majendie brought me a dark siliceous pebble, which, on being broken, exhibited a beautifully sharp example of the characteristic Lower Cretaceous shell *Pecten quinquecostatus*. The specimen was from an old collection, and appears to have been grouped with the well-known siliceous pebbles which are picked up in numbers in the deserts about Syene, where the Nubian conglomerates either crop out or have been denuded off ; and Mr. Etheridge informs me that he has never known the fossil to occur in the upper or flinty beds of the chalk.

One of the most curious problems in physical geography to be solved by geological inquiry is the true nature of that long meridional line of valley and, in part, of deep depression which extends from Akabah, on the south, through the Dead Sea, the valley of the Jordan, the lake of Tiberias, and the base of the Lebanon, and which, if prolonged (as appears to be consistent with facts) through the rich plain of the Bekaa, and by the course of the Upper Orontes, to the lake of Antioch, occupies some 500 miles in length. The observations of late years have proved what was little expected by the travellers of the earlier part of the present century—that the level of the Dead Sea is no less than 1292 feet* below the level of the Mediterranean ; and most of the hypotheses which have formerly been suggested to account for the formation of this remarkable valley must be rejected or modified in consequence of the measurements of the levels, which have now been made with undoubted exactness. When first the existence of the line of valleys (the Arabah) extending from the southern end of the Dead Sea to the Red Sea at Akabah, was made known by Burckhardt, it was natural to found upon it a theory that the river Jordan had once flowed through the whole line of valley to an embouchure at the Red Sea ; and the comparatively low watershed which, south of Ain Ghurundel, divides the run of waters flowing to Akabah from that which takes its course to the Dead Sea was attributed to a slight subsequent change of the levels over a limited tract. But the subsequent discovery of the enormous depression of the lake and

* The earlier observations of De Bertou, Russegger, and von Wildenbruch were all considerably in excess, giving a mean of 1416·7 feet. Capt. Symonds reduced it to 1312·2 feet below the sea ; and the report of Sir Henry James made it 1292 feet on the 12th March, 1865. This latter result, obtained by the party under Captain Wilson, is stated to be lower by 2½ feet than the occasional level of the water, and 6 feet higher than it sometimes stands in the early summer ; and it coincides marvellously with the level given by Lieut. Vignes of the French navy, viz. 392 met. or 1286 feet.

Jordan valley (the Ghôr, as it is called by the Arabs) led to the supposition that the salt lake had once, as a long inlet, been in communication by the Arabah with the Red Sea. Against this latter hypothesis it was at once objected that no shells or marine deposits of any kind have ever been found along the line of the supposed inlet; and latterly the barometrical measurements of various travellers have shown that the elevation of the central part of the Arabah is so considerable as entirely to set aside such a proposition, without the assumption of great subsequent disturbances of level. The latest observations, those of M. Vignes, give the altitude of this watershed as being no less than 787 feet above the sea.

One of the most modern travellers of scientific experience, Dr. J. R. Roth, whose numerous barometrical observations were calculated by friends in Germany after his untimely death from illness in the Antilebanon, has given a series of levels taken along the Arabah, which also it is difficult to reconcile with the older theories. Thus the height assigned by him to the main valley, where he entered it from the southern pass which leads into the Wadi Musa, is given at 640 feet, and at two hours' journey further south 570 feet, above the sea[*].

Yet the same author, writing in March 1858, inclines to the older hypotheses, guided, as it would appear, more by an adherence to ancient traditions and by general appearances than by sound geological observation. He believes that, without doubt, the Arabah is the ancient bed of the Jordan[†], that the great lake Asphaltites and the whole valley up to the sea of Tiberias were formed by the crowning in of gigantic hollows produced by the dissolution of beds of salt, and that the *quasi* volcanic phenomena to which old tradition assigned the destruction of the cities of the plain were caused by the combustion of strata of bituminous slate. Dr. Roth, however, was not aware of the obstacles which would be opposed to this view by his own measurement; for he seems to regard the highest point of the Arabah as being but a seven hours' camel's journey from the northern end of the Gulf of Arabah, at a salt marsh called Godián, which he estimates at less than 200 feet (whilst the calculated results make it but 106 feet) above the sea. His own levels, however, between this and Ain Ghurundel, with those of other observers, seem to establish the fact that the water-shed is higher by hundreds of feet.

The only resource, therefore, of those who hold to either of the above propositions was to suppose that the higher portion of the Arabah had been raised by an elevation connected with the protrusion of certain porphyries which make their appearance at intervals along the valley, as shown in Russegger's map.

[*] Prof. C. Kuhn's paper in Petermann's Geog. Mittheil. 1858, p. 3.
[†] Since writing the above lines, I observethat the late Dr. Falconer concluded that a narrow strait had once communicated between the Mediterranean, near Antioch, and the Red Sea at Akabah, and that the Jordan probably at one time flowed into the Gulf of Akabah,—also that, simultaneously with the upheaval of the Arabah ridge, the valley of the Jordan was depressed through a violent mechanical convulsion. (Falconer's Memoirs, vol. ii. p. 655.)

But M. Lartêt affirms that pebbles of this quartziferous porphyry are found in the conglomerates of the "Nubian sandstone," near Mount Hor, and that, as their eruption consequently took place before the depression of the older Cretaceous strata, the porphyries must, if there has been any recent elevation at all, have partaken of it in common with the Cretaceous and Eocene strata, for which movement the evidence is yet to be collected.

Under such considerations the Dead Sea must be allowed an independent origin, connected by a continuous water-flow neither with the Mediterranean nor with the Gulf of Akabah; and the chemical reasoning on the peculiar character of the various salts so largely dissolved in its waters lends a strong confirmation to such views; whilst if we test the phenomenon by the analogy of salt lakes in other countries, there is no difficulty in accounting for its saltness by the energetic evaporation, throughout a long series of ages, of all the waters flowing down into its basin.

However closely these two most recent observers may agree as to the antiquity of the grand chasm of the Ghôr, a great discrepancy of opinion arises with respect to the mode of its formation. Dr. Fraas looks upon it as a simple case of erosion from perfectly horizontal strata—a statement upon which we are compelled to ask, what has become of the eroded material? And reckoning up only the length from the north of the upper great lake to the end of the main hollow, south of the other, about 150 miles, with the vast depth and width of the entire depression, there is an astounding quantity of débris to be accounted for, which, if we are unable to keep open a water-route downhill to the Gulf of Akaba, leaves the hypothesis untenable. On the other hand, M. Lartêt, observing a slight easterly inclination on the Judæan side of the Dead Sea, and only higher strata exhibited there as compared with those that crop out on the opposite shore of Moab, adopts the view suggested first by Hitchcock*, that a fault or dislocation takes its course along the line of the valley, having a heavy downthrow to the west, and that, in fact, the present depression was produced by a relative descent of the eastern side of the hill-district of Judæa during the movements that raised the entire land from the sea. The soundings taken by the American Expedition, showing a gradual inclination from the western shore to a maximum depth of above 1300 feet near the eastern side, and the sudden plunging down to 900 feet depth of this latter coast, add probability to a theory much more in accordance with facts observed elsewhere than is the notion propounded some years ago by Russegger, that the whole breadth of the Ghôr had been a subsidence caused by deep-seated volcanic action.

Both Fraas and Lartêt concur with the observations of all geologists who have visited this region, that the volcanic appearances ascribed to it existed only in the minds of persons imbued with preconceived notions and ignorant of the character of the simplest stratified rocks; but, penetrating as he did through the mountains of the eastern coast, M. Lartêt was able to confirm the statements

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* Rep. Assoc. Amer. Geol. Boston, 1841–42, p. 348.

made by that accurate traveller, Seetzen, who, in 1807, described plateaux of basaltic lava as capping limestone hills at some distance from the lake. From some of the higher points, it would appear that *coulées* have flowed downwards through the valleys; and whilst the volume of these igneous rocks seems to be small as compared with what obtains in the country further northward, it is important to observe that their eruption must have been long posterior to the formation of the deep chasm, as proved by their flowing along the deep gorges which debouch upon its waters.

M. Lartêt has also done good service in tracing and describing with distinctness the strata of fine sediment which were deposited by the lake when it stood at a level higher by above 300 feet than at present. Furrowed and torn asunder by the rains and torrents of the wet season, these friable beds of marl and gypseous clay are seen, at various places near the borders of the Dead Sea, standing in cones and ridges and ragged plateaux, often of the most fantastic forms. In the peninsula of Lisan they were studied to the greatest advantage, but nowhere yielded a single fossil; and it may perhaps thence be fairly concluded that, even at that remote period, when the waves of the " salt sea" beat against the sides of the valley of the Jordan at least halfway up to Tiberias, its waters were already so far saturated with chlorides and bromides as to be unsuitable for the maintenance of animal life.

Change of Climatal Conditions.—Is the cause of this once very different surface-level of the Dead Sea to be sought in a former more abundant influx of waters resulting from a moister climate, or in a less vigorous evaporation than at present, or in both combined? and what has been the source of so great a change of climate between that time and our own? M. Lartêt suggests that the high water-level probably belonged to the Glacial period, when, as we have learned from Dr. Hooker, glaciers lay upon the flanks of Lebanon, and the temperature of Southern Palestine must consequently have been low enough to be consistent with a heavy rainfall and little evaporation. Should the startling novelty announced by Dr. Fraas be confirmed, of the traces of glaciers in Sinai, it would be a matter of high interest to connect them with the same period. It is argued also from the dimensions of the various watercourses which open upon the valley, and which are now in ordinary spring or summer weather mostly dry, that they must have been channelled out by powerful streams which have long ceased to exist; but in the absence of trustworthy accounts of the amount and volume of these streams in the winter season, those who are acquainted with the transformations connected with southern climates, and have seen the *fiumaras* of Sicily, the *ramblas* of the Alpujarras, and the *wadis* of North Africa, will hesitate before concluding the inability of the present rainfall to cut down the ravines on a large scale. It is nevertheless in favour of this argument, that several, at least, of these outlets are by no means worn down to the present level of the lake, but open upon it in the abrupt shores at such a height above its surface as to give the impression that the excavating action

of the stream is slight as compared with what it was of old. On the great change which must have occurred in the climate of the country, M. Lartêt proposes the following means of accounting for the phenomena :—

1st. That they are due to a general elevation of the temperature, increasing the rate of evaporation.

2nd. That the emergence of a large tract of land in the region from which the prevalent winds had come would cause them to arrive dry and hot instead of laden with moisture, and that the rise of the Sahara above the sea probably took place about this period.

3rd. Or that a lofty chain of mountains might in early times have been upraised in the path of the same winds, the cool summits of which would tend to condense the watery vapour, and thus to precipitate the rain which otherwise would have been conveyed to a greater distance.

A further question of high importance is answered in the affirmative by Dr. Fraas, viz. whether these climatal changes have not been continued during the historical period, and whether we have not, in the general absence of vegetable soil in Palestine, and in Egypt outside the area of Nile irrigation, as also in the contrast afforded between ancient records and present barrenness, sufficient evidence of a secular deterioration altogether independent of human agency.

As regards the probability of a great revolution in meteorological phenomena caused by the elevation of the Sahara, the Society is aware of the theory put forward a few years ago by the Swiss geologists, that the retreat of the vast ancient glaciers of the Alps was caused by the hot winds which arrived direct from that newly raised portion of Northern Africa. The violent *Föhn* wind, or " snow-eater", as it is sometimes locally termed, which, whether in summer or winter, so often impinges from the southward with fury upon the mountain barrier of Switzerland, is now pointed out, by peasant and naturalist alike, as the chief agency by which the snows and glaciers are kept in check. MM. Desor and Escher von der Linth visited Africa in 1863, especially for the purpose of inquiring into the subject, and, finding reasons for concluding that the Sahara has been elevated from the condition of a sea-bottom during the Quaternary epoch, were satisfied that they had obtained ample confirmation of the theory.

In his Address to the British Association at Bath, Sir Charles Lyell drew up a lucid and connected account of the various facts and their explanations which support the opinions first propounded by M. Escher von der Linth, and, admitting the correctness of the data, showed the undoubted marks of the change of climate which resulted from the prevalence, for a few days more or less, of the Föhn or Scirocco. At the same time he brought forward additional evidence for the existence in Posttertiary times, of a sea occupying the place of a great part of Northern Africa, and separating the highlands of the south and south-east from the hill-district of Algeria and the Atlas.

Professor Dove, the eminent meteorologist, who has for many

years advanced other views on the subject of these remarkable winds, has recently published* a careful examination of the whole question.

He cites early writings of his own, beginning in the year 1837, based on the principles of Hadley, and confirmed by the generalizations of Sir John Herschel, which show that the currents of heated air, rising from the parched regions of Central Africa, must partake of the more rapid velocity of the equatorial rotation, and, as they pass northward, gain on the surface of the earth in the slower-moving higher latitudes, and gradually get deflected on their course towards the poles, so as to assume the direction of south-westerly winds. In winter, he holds that the chief heating area will lie far to the south of the Sahara, and that the upper or return trade-wind (*obere Passat*) will turn off in such a direction, as not merely to miss the Alps in its northerly course, but barely to touch the southern corner of Greece. Its full force will thus sweep over Arabia and Western Asia to the regions of the Caspian, the Aral, and Central Asia. The hot winds which rise from the broiling African deserts may therefore, where they begin to descend again towards the surface of the earth, have been instrumental in promoting an unusual amount of evaporation in Syria and the Aralo-Caspian plains, whilst the Föhn would be derived from a more westerly origin, and probably from the South Atlantic and West Indies. But the Swiss authors object that the Föhn is a hot and very dry wind; and Dove thereupon quotes at length a series of observations and descriptions which establish the fact that these storms, when they break upon the Alps, are commonly, and in the winter especially, accompanied by heavy rains, and in the higher districts by thick downfalls of snow. The two instances more closely inquired into are the storms of the 6th and 7th January, 1863, and 17th February, 1865, when the "wild offspring of the desert," as the gale was termed by the Swiss papers, raised the temperature considerably, and, including in its train lightning, snow-storms, avalanches, and inundations, committed fearful havoc. In the second case it was particularly observable that, for some days before, the temperature had been lower than for forty years previously; and whilst the result of a warm dry wind impinging on this cold air would have been only to increase its capacity for vapour, that of a warm moist wind, under the same conditions, would be to condense the vapour, and to produce a fall of snow. And this latter effect is proved, by the accounts sent in from 58 different localities, to have occurred heavily almost throughout the country. About the same date, and for some days afterwards very stormy weather was reported from various stations in Italy, where the wind was mostly the Scirocco, the south-easter, which there can be little hesitation in accepting as identical with the Föhn.

The researches of Ehrenberg on the microscopic organisms contained in the red dust and "blood-rain" sometimes deposited by the Scirocco, are strongly in favour of ascribing to them a South-

* Ueber Eiszeit, Föhn, und Scirocco, von H. W. Dove. Berlin, 1867.

American rather than an African origin ; and the heavy storm of
28th February, 1866, was a south-westerly gale in Western Europe,
a Föhn in the Alps, and a Scirocco in Italy, accompanied by rain
with red dust.   It is true that these atmospheric currents may be
subjected to such obstruction or friction by coming in contact on
the north-west with masses of cold air, and on the south-east with
the heated air of Africa, as to be obliged to pursue a modified
course, and that in this way, a Scirocco *di paese*, a real land-Föhn
may be locally occasioned.   Under such conditions the line of Italy
and the Alps would form a border region, while the greatest baro-
metrical depression would occur, not in Switzerland, but in France,
and would, as in the storm of 23rd September, 1866, cause the
equatorial current to act with special energy in that country, and
thus to produce the most destructive inundations.

Professor Dove seems to admit that an occasional hot blast may
cross as a direct desert-wind in the lower regions of the atmosphere,
by the narrow sea-channel from Tunis to Sicily, and, sweeping up
overland, perhaps reach the Alps as a still dry wind.   But the
lively account given by Lorenz* of the ways and properties of the
two opponents, the Scirocco and the Bora, on the eastern coast of
the Adriatic, adds strong confirmation to the general statement that,
apart from local waifs and strays and modifications in direction, the
great bulk of the winds which descend hot and full of moisture on
these mountain-regions has ascended from land and ocean far to
the west of Africa, and that they are fulfilling the great purpose
of counteracting the tendency of the trade-winds, as they drag
over the surface of the earth, to retard the velocity of its diurnal
rotation.

A great amount of clear light has been thrown upon the climatal
conditions of our globe in various earlier stages of its history by the
researches of Prof. Oswald Heer†, who has recently published a brief
résumé on the fossilized remains of plants found in Iceland, Spitz-
bergen, North Greenland, Banks Land, and the north of Canada.
At the outset we are astonished at the wealth of the Arctic flora
proved to have existed in Miocene times; but when the indefatigable
Swiss botanist shows us so many instances of close analogy between
the extinct forms and the now living species of northern latitudes,
he dissipates the doubts which induced cautious reasoners to argue
for the probability of masses of trees and other vegetation having
been drifted from the southward to the now inhospitable shores
where they have been exhumed by our Polar explorers.   The pre-
servation of delicate leaves, the fact that insects are found with the
plants, the presence of fruits, flowers, and seeds, sometimes arranged
as they originally were in the berry, and the occurrence of the
vegetable remains in some cases (as in Spitzbergen) with fresh-

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* Physikalische Verhältnisse und Vertheilung der Organismen im quar-
nerischen Golf. 1863.
† " La Flore Miocène des régions polaires," par M. le Professeur O. Heer,
Bibl. Univ. Nov. 1867.   See also ' Flore Fossile des Régions Polaires,' par M.
le Prof. O. Heer : Zürich, 1867.

water deposits, sufficiently indicate that they can have been wafted for no great distance from the sites on which they grew. Thus the *Sequoia* (*Wellingtonia*) *Langsdorffii* was once the most abundant tree in the north of Greenland, and its remains are found as far south as the Miocene beds of Switzerland and Italy; and this example of a genus to which belong the largest trees in the world, and which once existed abundantly throughout the high latitudes, but especially in Iceland, is very nearly akin to *Sequoia sempervirens*, one of the two species which alone survive and which are exclusively confined to California. It is, perhaps, yet more surprising to hear of the beeches, chestnuts, oaks, and even vines which, in those far distant days, combined with a rich undergrowth of shrubs and elegant ferns to form a picture contrasting in the highest degree with the modern condition of that same Greenland, covered by one colossal glacier.

In the Miocene period, the northern limit of the limes, the *Taxodia*, and the *Platani* was the 79th degree of latitude, whilst that of the pines and poplars, if we may judge from what we now see, would reach 15 degrees further north than the *Platani*, or absolutely to the pole, or, at all events, the nearest land thereto. The great change of climate is rendered sufficiently obvious by observing that the present northern limit of trees is the isothermal line which gives a mean temperature of 10° C. (or 50° F.) in July, and which nearly coincides with the parallel of 67 degrees north latitude, never, therefore, entering within the polar circle; whilst in those days it even attained the pole.

Founding his opinion on the character of the flora, Prof. Heer concludes that the mean temperature of the year, in the Miocene epoch, was, in North Greenland, about lat. 79°, 5° C. (41° F.), whilst at the same period that of Switzerland would have been 21° C. (69°·8 F.), making a difference of 16° C. (28°·8 F.). At the present day the difference between the mean annual temperature of Switzerland (lat. 47°), reduced to the level of the sea, and that of Spitzbergen (lat. 78°) is 20°·6 C. (37°·08 F.), whence it is evident that at the Miocene period the general climate of northern Europe was more equable than now, and that the mean temperature diminished at a lower rate than the present between the temperate zone and the pole, having then been at the rate of 0°·5 C. (0°·9 F.), and being now 0°·66 C. (1°·2 F.) for each degree of latitude.

In endeavouring to find an explanation for these facts now placed so distinctly before us, Prof. Heer has examined a long series of the hypotheses which have from time to time been advanced. He declines to admit, for a moment, any supposition of the displacement of the poles, and objects as well to the older views as to the recently propounded theory of our secretary, Mr. J. Evans, which seeks to show that modifications of portions of the earth's crust may be attended by an actual movement of that rigid envelope over its internal nucleus.

Far more important, in the opinion of the Swiss botanist, is the speculation so admirably reasoned out by Sir Charles Lyell, on the climatal changes which must be produced by a new distribution

of sea and land. And yet, granting the most favourable circumstances, and assuming that, instead of the present irregular and unequal distribution of sea and land, we had the continents united near the equator, and only scattered islets left amid great oceans in the higher latitudes, the mean annual temperature would undoubtedly be raised in no small degree, but not sufficiently to admit of the growth of a rich vegetation between the parallels of 70 and 80 degrees. The very fact, however, of the wide distribution of this luxuriant Miocene flora shows that a large area of land was then amassed in the temperate and polar zones, and consequently that such explanation is inadequate to account for the facts.

Prof. Heer, like many others, is much tempted by the ingenious inquiries of Mr. James Croll on the results of the varying excentricity of the earth's elliptical orbit. The present tendency of its course is towards the form of a circle; and in 23,912 years it will have made its nearest approximation to that figure, and the excentricity will be at its minimum, or little above half a million of miles. At the present time the linear value of the excentricity is three millions; and when the orbit attains to the opposite extreme of form, it is above fourteen millions of miles. At present, also, the earth is nearest to the sun during the winter of our northern hemisphere, and furthest during our summer. But since, in the meanwhile, the relative position of the line of the apsides and that of the solstices is affected by a movement of revolution occupying 21,000 years for its completion, our northern summer will, in about 10,000 years, coincide with the perihelion, and the winter with the aphelion. Now, when this latter coincidence takes place at the time of maximum excentricity of the orbit, the hemisphere so affected must suffer an unusually high degree of cold: the moisture, in winter, would be precipitated as snow, and vast masses would be accumulated which the summer's heat would be unable to melt. The other hemisphere would in the meanwhile enjoy a temperate climate, like a continual spring. It has been calculated that such a concurrence of these elements of position took place 850,000 years ago, giving 36 days of winter in excess, a mean temperature in the latitude of London of 126° F. for the hottest, and −7° for the coldest month, and when it appears probable that the Glacial period was in force, —although only 50,000 years earlier, when the excentricity was at a minimum, the climatal conditions must have been entirely reversed[*].

Whilst, however, Prof. Heer leans to the opinion that some effect from these latter causes may have combined with that of geographical distribution of land and sea to produce changes of climate, and that the latter is probably the more energetic, as it is also the most securely deduced source of action, he looks further for assistance, and suggests the passage of our solar system through regions of varying temperature. This hypothesis was examined in detail by Hopkins, in his admirable paper on the causes which may have

[*] For a full discussion of the causes of vicissitudes of climates *vide* Lyell's 'Principles,' 10th edit. chap. xii. & xiii.

produced changes in the earth's superficial temperature[*], more particularly with reference to its being assigned as an explanation of the cold of the Glacial period, for which he proves it to be entirely insufficient. Mr. Hopkins showed, at the same time, that more might be said in favour of a *maximum* than of a *minimum* temperature acquired in this way, but yet that, if our sun were to approach a star within the distance of the planet Neptune, a case incompatible with the continued existence of the solar system in its present form, the stellar radiation would not send to the earth much more than the thousandth part of the heat which she derives from the sun. The inappreciable increase of temperature derivable from this source renders the hypothesis untenable so long as the reasoning of our lamented former President remains unimpugned.

The subject of the climate of former periods as contrasted with the present, and more particularly as connected with the phenomena of the Glacial epoch, has been elaborately handled by our foreign member Baron Waltershausen, Professor of Geology at Göttingen, in a treatise [†] to which the prize of the Haarlem Society has been awarded. His investigation reminds the reader of those sections of Mr. Hopkins's paper on Changes of Climate which discuss the position of the isothermals, the height of the snow-line under different circumstances, and particularly the extent to which elevation of the land in the Alps and in the Snowdon district may have caused the former extension of glaciers. But my esteemed friend the Göttingen Professor enters much more into the details of the geological phenomena so closely intertwined with the meteorology and the mechanics of the Alps, and brings to his aid the researches of other authors, published within the last few years. His work gives a general account of the history and the results of the observation of glaciers, of the indubitable former extension of the ice-streams far beyond their present limits on both sides of the Alps, and of the distribution of the erratic blocks, as checked and confirmed by often repeated visits to Switzerland, and further illustrated by journeys in Iceland and Scandinavia. It is Waltershausen's object to base the explanation of these facts, and of the great contrast to them presented by the climate of the Tertiary period, upon the firm foundation of weight and measurement, and to endeavour to prove that they are consistent with the doctrine of the earth's heat as propounded by Fourier, thus standing in need of no hypotheses or guesses, such as variable radiation of the sun, or hot and cold regions in space, which are unsupported by any other class of observations.

In order to estimate fairly the changes which may have taken place, we must consider the several conditions on which the climate of a given locality is dependent, viz. :—

    1. Its altitude above the sea-level.

    2. Its geographical latitude.

    3. The distribution of land- and sea-surface.

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[*] Quart. Journ. Geol. Soc. 1851, p. 60.

[†] 'Ueber die Klimate der Gegenwart und der Vorwelt,' von W. Sartorius von Waltershausen. Haarlem, 1865. 4to, 388 pp.

 4. Hygrometric condition of atmosphere, cloud-formation, and
    rainfall.
 5. The currents of the air and sea.
 6. The internal heat of the globe.

The effect of the latter, being at present valued at only $\frac{1}{30}°$ C.,
may be neglected in questions relating to recent periods, although
it must, in all probability, have formed an important item at the
time of the more remote geological events.

The decrease of temperature for a given amount of elevation in
the air is so distinctly dependent on the latitude of the place (being
more in the polar and less in the equatorial regions), that a formula
may be established by the aid of which the mean temperature for
any required elevation, under a certain latitude, may be approxi-
mately calculated. But it is requisite for this purpose to know the
mean annual temperature of some neighbouring locality of measured
height above the sea ; and thus a comparison of the observed con-
ditions of sea-climate and land-climate respectively has to be insti-
tuted, from which it comes out, among other deductions, that in the
latitude of 33° 24' in our northern hemisphere the mean annual
temperature of a totally marine and of a continental climate would
be the same, whilst northward of this parallel the mean tempera-
ture of the land-climate would be colder, and southward would be
warmer, than that of the oceanic climate. And the ultimate con-
clusion is, that although the unsymmetrical distribution of land and
sea on the earth's surface must exercise an undoubted influence on
the advance and retrocession of the glaciers, it is not adequate to
account for the glaciers of the Diluvial period.

The relation of an oceanic climate to glaciers has lately received valu-
able illustrations from the writings of Drs. Haast and Hochstetter,
on the Southern " Alps " of New Zealand. Their chief results are
given in the last chapter of the sumptuously printed and illustrated
volume which has recently been published by the latter geologist*.

Here, in the latitude of 43° to 44° S., whilst the average lower ter-
mini of the glaciers on the east side of the ridge are much higher, the
great Tasman glacier descends to 2774 feet above the sea-level ; but
on the western side of the ridge the Francis Joseph glacier, although
of much smaller volume, reaches no less than 2000 feet lower, or to
a height of but 705 above the sea. This strange contrast is accom-
panied by the notably heavier precipitation, and the frequent cloud
and mist of the western coast. And as the large development of the
glaciers, generally, in this region seems attributable to the equable
and humid oceanic climate, so the exceptional advancement of the
foot of the Francis Joseph glacier among the vegetation of the low-
lands is to be explained, not by a low mean annual temperature, but
by a peculiarly low temperature of the summer †.

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* New Zealand, its physical geography, geology, &c., by Dr. Ferdinand von
Hochstetter. Stuttgart : J. G. Cotta. 1867.
† The mean annual temperature of Christchurch was $53\frac{3}{4}°$ in 1864, that of
the summer $61\frac{1}{4}°$, and of the winter $44\frac{1}{4}°$. It is believed that the annual average
on the west coast is very similar.

Von Waltershausen has further been bold enough to investigate and state the mean temperatures of different regions of the earth's surface in early geological epochs, beginning with the Silurian. He argues that this may fairly be attempted only on the supposition of a slow and uniform change in one direction, in accordance with the theory of Fourier, and on the assumption that a much larger proportion of the earth's surface was covered with sea in those early times than at present, when the ratio of dry land to sea is about 2 to 5.

The calculation has to be based on that hotly disputed and still very uncertain element, the thickness of the earth's crust, which, taking the mean density of the earth at 5·67, and the mean specific gravity of lavas at 2·912, derived from the depth where the rigid and the fluid constituents would be in contact, he estimates at about 66 miles English, or $\frac{1}{60}$th of the earth's radius.

Upon this foundation several curious tables are calculated, showing what would be the temperature of the surface with a given thickness of solid crust, at what depth, in each case, the boiling-point of water would occur, and the mean temperature of the different latitudes at the epoch of the several geological formations. But in their application these results are vitiated by the author's having ignored the presence of stratified formations beneath the Silurian; and the comparatively recent discoveries of Sir William Logan have sufficiently proved to geologists the enormous errors which may result from our imperfect knowledge of the stupendously thick and long continued deposits which have preceded the formation of what we were accustomed to consider the lowest series of truly sedimentary rocks.

Returning, however, to safer ground, the Baron examines and rejects the various theories which have been brought forward to explain the evidences of the former great extension of glaciers in the Alps. Influenced by the Lyellian doctrines, he is no believer in the catastrophic action which many authors have connected with the upraising of that great chain of mountains, but requires a long period of time for the gradual elevation of the entire mass, beginning near the end of the Tertiary period, when the Molasse and Nagelfluhe had already been deposited. When the main range at this time began to emerge from the waters, a long gulf or arm of the sea lay stretched along the north side of the Alps, which, as may be seen from the geological maps, extended westward round to Marseilles, and eastward away beyond Vienna into Hungary. All the larger lakes of Switzerland and of the Bavarian highland are situate in this zone. As the higher parts of the ridge rose into the region of perpetual snow, the formation of glaciers began, the streams of which would come to an end when they descended to a stratum of atmosphere having a mean annual temperature of about 2° R. (36°·5 F.). Whilst, then, this arm of the sea remained at its original level, it would have a mean temperature of at least 10° R. (54°·5 F.), and the lower end of the glaciers would be still from 3500 to 4700 feet above the water-level. Oscillations seem to have taken place, as in

the Purbeck period, which caused the alternation of freshwater and marine deposits on the flanks of the mountain-chain. And when, in the Diluvial or Glacial epoch, the elevation had reached its maximum, the height attained by the upper peaks and ridges was due, first, to their having been formed of a quantity of material which has since been worn away, and, secondly, to the whole range having been bodily lifted upon a higher base or pedestal, from which position it has again descended by gradual depression between the time of the greatest extension of the glaciers and our own day.

If we examine the mean height above the sea of the termination of the glaciers of the Bernese mountains, it proves to be, for a mean latitude of 46° 33′, 4633 feet, and for those of the Savoy and Pennine group, in mean lat. 45° 55′, 4834 feet, giving a difference which would amount to 317 feet for one degree of geographical position. Calculating thence for a general mean north latitude of 46° 11′ 3″ a height of 4693 as the terminal height of the glaciers, it will be found coincident with a mean atmospheric temperature of 3°·7 C. (38°·72 F.); and at a height corresponding with this temperature the ancient glaciers, whose relics are now found at much lower levels, must also have come to their termination.

Taking now for comparison the terminal moraines (Steinwälle &c.) which mark the former limits of the great glaciers of the "diluvial" period on the north side of the Alps, we have, for a mean latitude of 46° 55′ 7″, a height of 1416 feet above the sea, to compare which with the present mean height of 4693 feet, we may reduce both to the same position in latitude (that of Monthey), 46° 15′, and shall then have the respective heights of 4673 (h) and 1202 (h') feet. Assuming further, that the mean annual temperature in the so-called Glacial period was higher than the present by 0°·19 C., by virtue of the earth's internal heat, a further lowering of level by 90 feet would have to be allowed for the terminus of the glaciers of those times.

We should then, on this principle, require a depression of the north side of the Alps, since the period of the great glaciers, of

$$h - (h' - 90) = 4673 - 1112 = 3561 \text{ feet}*,$$

and by a similar inquiry, for the south side of the Alps, reduced to the mean latitude of Ivrea, as the centre of these phenomena along the southern flank of the chain,

$$h - h' = 4920 - 890 = 4030 \text{ feet};—}$$

whence, with a limit of error of $\pm$ 190 feet, it may be inferred that the southern side of the great chain has been depressed about 500 feet more than the northern since the time of the great development of ice and snow.

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* A very similar result was indicated by Mr. David Milne Home, Edinb. New Phil. Jour., soon after von Waltershausen's treatise was sent to the Haarlem Society, viz. in 1861. Taking the average elevation of the melting point of Swiss glaciers at 4400 feet, and the height of Geneva as 1335 feet, above the sea, Mr. Home takes the difference, or 3065 feet, as the height to which that part of Switzerland, would have to be raised to cause such a temperature as would enable the glaciers to reach Geneva without melting.

The inland sea which at the commencement of the elevation of the Alps occupied the space between the northern flank of the chain and the Jura, and covered a much greater breadth between Salzburg and Ratisbon, was contracted to so narrow a strait near Chambéry, and again on the south of Linz, in Upper Austria, as to render it a very probable hypothesis that a comparatively moderate oscillation or change of levels would close as it were the sluices, and alter the conditions of the basin from a marine inlet to a great lake—from a smaller Baltic to a Lake Superior. The beds of the Flysch, charged in places with fucoid remains, and alternating with the clearly Eocene nummulitic bands, are characteristic of the shore of this ancient arm of the sea, whilst the strata deposited in brackish water, described by Heer under the term of the Aquitanian *étage**, supply a satisfactory testimony of the slow secular change under which the marine conditions disappeared ; and a vast brackish lagoon formed the intermediate stage. The freshwater deposits which followed, at a period when, as M. Heer agrees, the level of the lake was at no great height above the sea, would belong to a district with a mean temperature (at sea-level) of 10°·52 R. (55°·5 F.), like that of Milan, whilst the winter will have been that of Catania, and the summer that of South Germany. A downward movement ensued, which reopened the communication with the Mediterranean ; and the vast lapse of time which was occupied in the changes of level seems to be expressed by the fact that the marine organisms again migrated, and spread themselves with the abundance of a full development over the entire region.

The renewed blockade of the straits was followed by the destruction of all sea-life, by a further deposit of freshwater strata (the upper Molasse), and, according to the theory under review, by the last great elevation of the Alps, which, lifting the entire region, as the west coast of South America has been raised bodily in recent times, transferred the lake and its borders by slow degrees from an almost subtropical climate to one of more temperate character (as witnessed by the lignite or slaty coal of Utznach, Dürnten, &c.), then to a colder one, and ultimately to one of boreal rigour.

If we consider the lakes of Switzerland to be the relics of this former inland sea, their basins divided from one another and modified in form by the unequal action of the physical forces to which they have been subjected, and that their mean height above the sea is 1325 feet, we shall have, by the addition of 3561 feet, or the amount by which it has been already calculated that the north side of the Alps had been uplifted, a total height of 4886 feet as the elevation of its waters above the sea-level.

The climate of the great Alpine lake and its banks may be readily calculated: the mean annual temperature would be 2° R., or 36°·5 F., the mean temperature of the hottest month 51°·8 F., and the coldest 21° F.; and whilst this would show a close resemblance to the climate of the northern part of Norway, the proximity of large bodies of water would doubtless cause a greater atmospheric precipitation

* Heer, Urwelt der Schweitz, pp. 275 and 282.

on the mountains than occurs at present *, and would thus furnish an additional quota to the bulk of the glaciers.

It was under these conditions, with glaciers creeping forth from all the deep valleys, either into the waters or over the surface of ice which coated the lake during a long winter, that erratic fragments of the older rocks, entangled in or supported upon icebergs and floes, were drifted across to the opposite shores, and there formed the long lines of gravels and boulders, and effected the scoring and polishing of the rocks, for which the long range of the Jura has attracted in so great a degree the attention of observers.

The Swiss geologists, and among them Professor Heer, look upon it as probable that there have been two Glacial periods—one before and the other after the deposition of the brown coals of Wetzikon, Utznach, &c. This alternation of conditions may be explained by oscillations of level, such as have been observed and inferred for other districts and other formations ; but, if considered independently of the amount of elevation of the land, it would need the hypothesis of a twice-repeated decrease and increase of the mean annual temperature by above $12\frac{1}{2}°$ F.—an irregularity inconsistent with the theory of terrestrial heat.

When at length the final depression of the district began to take place, Waltershausen shows grounds for inferring that it was by very slow degrees, and with unequal progress of subsidence, whence he agrees with Studer that the present lakes mark the tracts in which the variableness of the movement produced the deepest hollows, and argues that the stone-heaps (*Steindämme*) which border the lower end of so many of the Swiss lakes, are not actual moraines, but consist of the drifted blocks and débris transported by the later action of floating ice-masses, when the upland lake had, in the course of constant depression, been reduced to within these narrow limits.

Turning to the south side of the Alps, it is shown that a long marine gulf extended from Venice and Chioggia to the foot of the maritime Alps, from which a number of long inlets, or fiords, extended northward when the elevation of the Alps commenced. If it be sought to explain the former great extension of the glaciers along the valleys on this side of the chain without having recourse to a general elevation of land, we must introduce the supposition of a decrease of the annual mean temperature by about 10° C. (18° F.), an amount which cannot be expained either by a succession of cold years, on Charpentier's hypothesis, or by a different distribution of land and sea.   But if an elevation to the amount of about 4000 feet be assumed to have occurred, the phenomena will be accounted for, as on the north side of the chain ; and the subsequent gradual depression will have broken up still further into isolated basins that district of lakes, many of them formerly in communication with each other, which may be regarded as the remnant of the ancient Lombardo-Venetian gulf.

I must not attempt to follow out the numerous facts observed in

* The exceptional exceeds the average rainfall of the present day in Switzerand by about 10 per cent.

Scandinavia and Iceland from which Baron Waltershausen gathers confirmation for his theory; but from these, and from the glacial phenomena described for various tracts throughout Europe, he concludes that the total area to which they refer is but a small fraction, say six per cent., of the whole of that quarter of the globe; that the glaciers were never more than local streams, due chiefly to elevation of the land, and that the effects of the drift-ice, or bergs and floes, might be produced by a moderately reduced mean winter temperature, and require for their explanation no general reduction and no degree of cold incompatible with Fourier's theory of heat.

Taken in a general sense, these views gain in probability what they lose in originality, when we look back to Mr. Godwin-Austen's account of the superficial accumulations of our south-western coasts, and find him stating that he can only explain the facts by *an elevation of great amount, such as would place the whole of the higher portions of this country in regions of excessive cold*[*]—nay, more, that whilst disbelieving in the " Glacial period", as propounded by Agassiz, he would infer that a great elevation had at the same time affected a large part of Europe, and that the Alps must at one time have attained an altitude equal to that of the Himalayas.

The Society will not have forgotten that, in his elaborate and philosophical paper " On Changes of Climate," our former President, Mr. Hopkins, examined at some length the hypothesis of producing by local elevation of the land a great degree of cold to account for the former extension of glaciers in the Alps and North Wales. He was inclined to consider it untenable, first, on account of his estimate that an elevation of at least 6000 feet would be required in the former, and 7000 or 8000 feet in the latter case; and secondly, because " all geological experience assures us that no such mountain-range exists without numerous dislocations and other phenomena of elevation having determinate relations to the elevated tract." After a careful review of his reasoning, I cannot but think that the objections to such a view of the causation of a glacial temperature are in great part removed by the detailed comparison of observed facts made by von Waltershausen leading to the requirement of no excessive alteration of altitude; whilst, on the second score, that geologist must indeed be extravagant in his demands for evidence of mechanical action, who is unsatisfied with the " accidentation" of the Alps, or with the strange medley of lines of fault, dyke, and fold so wonderfully exhibited in Prof. Ramsay's map of the Snowdonian country. Nor is it allowable to treat the question as if the elevation of the mass of land in these districts, with its subsequent depression, were a new kind of requirement, when for many years past we have been familiarized with the proofs of the upheaval of these very mountain-tracts to considerable altitudes, and at periods separated by no great interval from that under discussion.

Geology of Savoy.—Not only geologists, but all Alpine tourists gifted with any power or desire of observation, will be thankful to M. Alphonse Favre for the labour of love which he has just com-

[*] Quart. Journ. Geol. Soc. 1851, p. 130.

pleted in a full account of Savoy and the adjoining parts of Pied-
mont and Switzerland*, illustrated by an atlas of plates, which unite
in an unusual degree the truth of geological sections with the varied
outline of charming picturesque mountain-groups.

The conscientious manner in which our eminent Foreign Correspon-
dent has explored and described the elevated region ranged around the
towering centre of Mont Blanc is well known to most of our Fellows ;
and it is only two years since our lamented friend Mr. Hamilton,
in his Presidential Address, took occasion to follow out at some
length one of the most interesting of M. Favre's chapters, as then
published in the Bulletin of the Geological Society of France, viz.
that on the gradual advance of observation and argument which,
after the lapse of many years, established the fact of the presence of
the carboniferous formation in the Western Alps.   A large portion
of the work is, indeed, of a somewhat historical character, since the
author, whenever he approaches a subject connected with puzzles and
theories (and how many of them hang about that classic region !),
deems it but just and satisfactory to state fairly the opinions of all
previous writers on the same topic, and adds his own objections and
propositions with a moderation which suits the character of a philo-
sopher who concedes to others the credit of having done their best
with the knowledge that was open to them, and compares without
prejudice their views with the phenomena which he practically
investigates.

Thus, in his discussion of the cause and effects of the ancient
extension of the glaciers, we are supplied with a review of all the
more notable hypotheses connected with the ice, and with the part
assigned to it in the scooping out of lakes.   He combats, as we have
seen for years, with many arguments the doctrine of Prof. Ramsay,
and is not less opposed to the half-and-half measure of De Mortillet,
who, whilst objecting to the competency of glaciers to erode solid
rock, claims for them the power of *affouillement*, or the excavation
of all the accumulated *débris* which he considers to have once filled
the lake-basins.   M. Favre, noting the position of the lakes on the
fringe of the higher Alps, and along a line where physical action on
a grand scale has dislocated, contorted, and inverted the strata,
connects their formation with the structure of the rock-masses ad-
joining, although he allows that the direction of the main lines of
valley has doubtless aided in the determination of their position,
and that it is impossible to deny that the valleys, after their forma-
tion, have been cleared out (*déblayées*) and enlarged by currents
and glaciers.

Among the most interesting of his chapters are those on the
Aiguilles Rouges, and on Mont Blanc itself, with a review of the
numerous and often very divergent opinions promulgated by succes-
sive geologists who have examined the peculiar structure of these
masses.   Beginning with De Saussure, we have a long list of ob-
servers who are satisfied that the crystalline schists on the flanks of

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* Recherches géologiques dans les parties de la Savoie, du Piémont et de la
Suisse voisines du Mont Blanc. 3 vols. 8vo, with an Atlas. Geneva, 1867.

these mountains, as well as the granitic rock, the protogine, constituting the central part of the ridge, are actually stratified ; others consider the divisions to be laminæ of foliation ; Mr. Daniel Sharpe took them for planes of cleavage.   All except the latter writer were struck with the fan-shaped arrangement of the laminar masses, a structure which is reproduced in the St. Gotthard and other nuclei of the central Alps, as well as in the eastern continuation of the great chain.   The sharp needles of rock which lend a special charm to these scenes, and were strangely imagined by De Luc to have been each independently thrust up from the interior of the earth, are but the narrow ends of almost vertical tabular masses, which viewed from the side form serrated ridges, but seen *end-on* appear to soar as mere isolated points to the sky.

Close alongside of some of the most marked of these, M. Favre has traced the boundary between the granite and the crystalline schists ; and he adheres to the old statement which has provoked so much discussion, that the schists thus appear to underlie the granite, and as indubitably to overlie the beds of fossiliferous secondary limestone*.   His own transverse section explanatory of the facts has been before the public for some years, and is the most probable that has yet appeared.   The powerful lateral pressure called into action by the upheaval and depression of the chain has produced parallel lines of close flexure, forming a narrow and steep synclinal trough under the valleys on the north and south of the Mont-Blanc mass, and an anticlinal in the main ridge.   As the elevation continued, the abutments of the central arch would be squeezed closer together, whilst the upper portion of the great fold of strata was not similarly supported, and would thus tend to bulge, and to throw the beds which were at first the lowermost in order into a position overhanging what were the upper.   Meanwhile a gigantic denudation must be supposed to have taken place ; and, as M. Favre is fortified by his investigation of that most remarkable outlier of lias and jurassic strata capping the loftiest peak of the Aiguilles Rouges, 9660 feet above the sea, the speculation hardly seems too hazardous that the same band of secondary formations at one time completed its loop above the summit of the whole Mont-Blanc range.

If a similar reasoning be allowed to hold good for the cretaceous and nummulitic beds, of which there is every probability that they at one time covered the Aiguilles Rouges, and have been subsequently removed by denudation, it would add to the present height of Mont Blanc a thickness of at least 4100 feet of rock.   There would thus have been carried away by denuding agencies from the group (massif) of Mont Blanc alone, and since the comparatively recent epoch of its attaining its full altitude, about 100 cubic miles of solid material.

Composition of Crystalline Rocks.—M. Favre's frequent excursions

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* The reader may be referred on this subject to Gen. Portlock's Anniversary Address to the Society, in 1857, giving figures of the rock-structure and of the excavation carried out by Mr. Ruskin near Chamouni, to settle what appeared to some to be a doubtful question.

have enabled him to give abundant detail on the characters of the crystalline central range of the Savoy Alps. The time-honoured protogene is fully confirmed by him in its original dignity of the chief prop or centre-piece of the whole, although, since the studies of M. Delesse, it is allowed that it belongs, as a distinct variety, to the group of the granites. It consists of five minerals, viz. quartz, orthoclase, oligoclase, a mica with iron-oxide base, and talc, and, as a general rule, appears to possess a more truly granitic character in the central parts of the formation, a schistose one towards the flanks. The presence of this second felspar, oligoclase, in these great Alpine nuclei is a point of great interest in the comparison of these with other granite rocks, as well as in the chemical changes and disintegration to which its composition peculiarly exposes it. As regards the *gisement* or geognostic position of this rock, he states his opinion, 1st, that it is stratified, and, 2ndly, that it never penetrates in the form of veins or dykes into other strata, as does the true granite, which is found, although rarely, here and there in this Alpine district—moreover, that by the forms in which it weathers it may be distinguished, even at a distance, from the granites, and that, although formed at a very ancient period in the history of the globe, it has only made its appearance at the surface within a comparatively recent time.

When we follow him into the domain of theory, the Geneva professor leads us into a misty region of somewhat audacious speculations. To him the commonly received view of metamorphism is a grossly exaggerated mysterious process, which he conceives to be entirely incapable of having formed the crystalline schists. He carries us back rather to a primeval period, when he supposes the whole of the now existing surface waters to be floating as vapour in the atmosphere, and to exert a pressure of 250 atmospheres. Added to this he infers that the subterranean water would make as much more, and would thus give a total pressure of 500 atmospheres. The carbonic acid which has since been fixed in the coal-beds would not add greatly to the weight of this crushing atmosphere; but the same gas which has been locked up in the limestones and other carbonates is estimated by him at 210 atmospheres more, and would thus give a grand total of 710 atmospheres which then weighed upon the surface of the earth.

Under this pressure, at which water would only boil at 480° C., or 896° Fahr., and when the temperature of the crust began gradually to diminish, the first precipitations and erosions would form a sediment which would be highly crystalline, and would in fact produce the granites and protogenes. Then, as the pressure and temperature were further decreased, the crystallization would be less marked, whilst the stratification would be more pronounced, and there would be deposited successively the crystalline schists and, at length, the clay slates. As for the original rock from which this first degradation took place, it would be lava; and our author, overriding the great and marked differences between the two *magmas* of Durocher,

or the basic and the acidic crystalline rocks, founds his reasoning on a comparison of the ultimate composition of the granites with certain lavas of Monte Nuovo, with pumice and obsidian, whilst he conveniently ignores the differences of composition which tell against him. The simplification of the history of the earth which M. Favre claims as the merit of his hypothesis, will not, I fear, rescue his views from the severe onslaught of critics who, whether they belong to the Plutonic or to the Metamorphic school, will be slow to accept a doctrine based on an unproved intermingling of rock-substances essentially different in mineral constitution as well as ultimate composition.

M. Favre's statements on the petrological characters of the central parts of the Mont Blanc chain recall the conclusions arrived at, after a long series of analyses, by our talented associate the Rev. Dr. Haughton, who first, as I believe, discovered oligoclase to be an ingredient of some of our British granites, and drew an interesting parallel between those of Donegal, in Ireland, and the analogous rocks of Canada, Sweden and Norway, and Mont Blanc. With regard more particularly to Ireland, I am indebted to Dr. Haughton for the following *résumé* of his conclusions on this class of rocks.

The granites of Ireland are divisible into *three* distinct groups :—

    I. The granites of Leinster.

    II. The granites of Mourne and Carlingford.

    III. The granites of Donegal, Mayo, and Galway.

I. *The Granites of Leinster.*—These granites are, geologically, newer than the Lower Silurian, and older than the Carboniferous strata. Mineralogically they are identical with the granites of Cornwall and Devonshire. They are composed of :—

    1. Quartz.   3. Margarodite.

    2. Orthoclase.   4. Lepidomelane.

They are therefore, in composition, quaternary granites; and their paste probably contains minerals different from those found crystallized in distinct masses. Like the Cornish and Devonshire granites, they are occasionally traversed by mineral lodes, particularly lead-lodes, which seem to have been formed in both countries at the same geological epoch.

II. *The Granites of Mourne and Carlingford.*—These granites are, geologically, newer than the Lower Silurian formation, and also newer than the Carboniferous Limestone, which has altered them into remarkable syenites on their southern and western flanks; mineralogically, they are composed of :—

    1. Quartz.   4. White mica (margarodite?).

    2. Orthoclase.   5. Black or green mica (lepidomelane?).

    3. Albite.

They are, therefore, quinary granites, and differ from all granites hitherto described by mineralogists in containing *albite*. These granites, when they have intruded into the Carboniferous Limestone on their southern and western borders, are converted, by a species of endo-metamorphism, into syenites of different kinds—more especially, near Carlingford, into a syenite composed of augite and

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anorthite, which is unique as to its composition among British rocks *.

III. *The Granites of Donegal, Mayo, and Galway.* — These granites are identical in character with those of Scotland, Norway, Sweden, and Finland, and, as such, resemble the granites described by Rose and other chemists. They differ from the granites I. and II. in being stratified and not intrusive, and therefore vary considerably in different localities, according to the beds from which they have been formed by metamorphic action.

Geologically speaking, they may be regarded as belonging to the most ancient of the stratified Scandinavian rocks, and consequently as much older than either the Leinster or Mourne granites. They are not yet proved to be of an age corresponding to the Laurentian rocks of America, although it is very probable that they are so.

Their mineralogical constituents are :—

1. Quartz.	4. Margarodite.
2. Orthoclase.	5. Lepidomelane.
3. Oligoclase.	

They are, therefore, quinary granites, and are identical with the granites of Sweden and Norway, from some of which they cannot be distinguished, either by the eye or by the more refined test of chemical analysis.

They differ from the Laurentian stratified granites in not containing either labradorite or andesine; for the existence of such minerals in them has not yet been proved, though often guessed at.

Labradorite is found in abundance in the stratified granites of Eggeroe, in Norway, and in the gneissose granites of Labrador and Canada, but has not yet been found in Ireland or in Scotland in rocks of the true granite type.

The celebrated hypersthene and labradorite syenite of Scavig, in Skye, can scarcely be regarded as part of the granitic series of rocks of Scotland.

In the discussion of the mineralogical composition of the granites of Ireland, Dr. Haughton has adhered to the principle that we are not entitled to assume in any rock the existence of any mineral whose independent existence in that rock has not been proved. By a strict adherence to this principle, he believes he can confidently state that the results he has obtained, though they may be *modified*, cannot be *refuted* by further investigations, and that they will bear the test of time.

The details of the discussion itself belong to the region of elimination of variables among simple equations, and are familiar to every algebraist, from the time of Bezout to the present day. There is no originality in them, he adds, except such as belongs to the subject to which he has succeeded in applying them.

It remains to be borne out by further observation whether the above divisions can be relied on in a larger sense ; but from what I have myself seen of the granitic rocks in several of the districts

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* Dr. Haughton's investigations as to the composition and origin of these granites are not yet completed.

above named, I am inclined to think that a really metamorphic
origin may with much probability be assigned to the quinary com-
pounds just mentioned for north-western Ireland and Norway, as
also for that of the Western Alps, whilst other varieties of granite
undoubtedly occur under geological conditions so dissimilar as to
require a different view of their formation.

The various associations of the minerals which compose the igne-
ous rocks have received close attention in a work which has just
emanated from the pen of our laborious Foreign Correspondent Dr.
F. Senft*, in which the formation, the decompositions, and the che-
mical changes of mineral substances are enumerated with a fulness
of illustration which cannot but be highly useful to geological in-
quirers. His chapter on the family of the felspars is especially
welcome, as discussing the newer views which have been brought
forward upon a group of mineral species so important to the geologist.
Dr. Gustav Tschermak, in a valuable paper read to the Academy of
Sciences at Vienna, in 1864†, had proposed to simplify the subject by
considering that there exist only three distinct kinds of felspar, viz.
adularia, or the potash-, albite, or the soda-, and anorthite, or the
lime-felspar, whilst the others, which by previous authors have
been described as distinct species, are but mixtures of the above
kinds. Thus most of the opake orthoclase is, according to him, a
compound of adularia and albite, whilst oligoclase and labradorite
are, similarly, various mixtures of albite and anorthite. It is true
enough that the lamellar alternations of orthoclase and albite ob-
servable in the crystals from several localities, the coating of ortho-
clase with a rind of oligoclase in Finland, and the relation between
the composition and the crystalline forms of the several species
render a part of these views extremely probable. Dr. Rammelsberg,
in a recent review of the subject‡, is satisfied that the best analyses
prove that the felspars containing lime and soda together are iso-
morphous compounds of pure lime-felspar (anorthite) and pure soda-
felspar (albite), the isomorphism of which as a whole does not
depend on the number or the equivalence of the elementary atoms
which compose those species. He holds that this reasoning is far pre-
ferable to the view of such a mineral being a mixture of anorthite
and an analogously constituted soda-compound, a soda-anorthite,
and recognizes also mixtures of different species in the oblique or
monoclinic felspar containing lime, iron, potash, and soda, or baryta.
The speculations which flow from such a view of the juxtaposition of
these mineral species, embracing the visible peculiarities of structure
and the frequent curious changes which have modified the grouping
of their ingredients, will affect more deeply than we had expected
the reasoning on the genetic relations of the crystalline rocks.

Many of the topics connected with the foregoing minerals, and
rock-structure at large, are examined in a somewhat novel point of
view by Dr. Vogelsang, in his recent work on the Philosophy of

* Die krystallinischen Felsgemengtheile, von Dr. Ferdinand Senft. Berlin,
1868.   † Poggendorff's Annalen. Bd. cxxvi. S. 39. 1865.
‡ Zeitschrift der deutschen geol. Gesellschaft, 1866.

Geology, and on Microscopic Studies of Rocks*. The volume is, in three simple words, "England's Geologen gewidmet," dedicated to England's geologists, and, after a first division dealing with the auxiliary sciences, devotes a second to the history of the development of geology, in which our British chiefs in geological theory play a very prominent part. His review of the series of leading authors and philosophers, from the time of George Agricola to our own day, is couched in a bright and vivacious style; and an unusual originality and independence of judgment are shown in the various degrees of merit allotted to the great names of the science. The third division of the book opens with the newer phases of geology, and, ascribing to our valued associate Mr. H. C. Sorby the full credit of introducing so important a step in the development of petrography, enters upon the microscopical examination of a series of sliced rock-substances, selected in a great measure for their relation to various moot points in theory.

In opposition to certain recent observers who assert that by the aid of the microscope they have been able to resolve the whole of a porphyry, including its " paste " (*Grundmasse*), into a compound of recognizable crystals, Dr. Vogelsang insists that, just as nebulous matter in the heavens has proved irresolvable under the highest power of the most powerful telescopes, so the paste of a great number of the porphyries is a decidedly uncrystallized mass, and, further, that the form of the cavities, and the position of the minute crystals or *microlites* contained in it, testify to the mechanical action of the movement of a more or less liquid substance.

Whilst agreeing with Mr. Sorby in the facts of observations upon the fluid-cavities or water-pores contained in the quartz of quartziferous silicate rocks, he draws a different deduction from their presence. It will be recollected that these microscopic cavities are only partially filled with liquid, and that, from the relative size of the bubble, Mr. Sorby suggested that conclusions might be drawn as to the temperature at which the mass had solidified. Dr. Vogelsang finds that the ratio of the bubble to the cavity is not constant in the same rock, or even in the same crystals, and holds that the fluid has been introduced by secondary action into the cavities. Mr. Sorby, in his original paper, read before the Society in December 1857, had not omitted to discuss this alternative, especially with reference to the fluid-cavities in the nepheline of Monte Somma, and in the quartz of granite and elvan; and he then alleged such good reasons for doubting any other explanation than that of the fluid having been enclosed at the time of formation of the mineral, that we shall need further evidence to lend support to an opposite view. The issue of the question will awake much interest when it is recollected how ingeniously Mr. Sorby deduced from his microscopic vacuities, among other things, the inference that the granites of Cornwall and Aberdeen were consolidated under pressures varying from 50,000 to 78,000 feet of rock.

* Philosophie der Geologie und mikroskopische Gesteinsstudien, von Dr. H. Vogelsang, Professor zu Delft. Bonn, 1867.

Another investigation, of great interest, is that of the quartziferous porphyries as compared with recent quartziferous eruptive rocks. The analogy of the microscopic structure of the two series is said to be complete, admitting that in the older one a molecular change has taken place. The newer volcanic rocks of trachytic character, including those of Java, of Campiglia, the Euganean Hills, and the rhyolites of Hungary, exhibit in their imbedded grains or crystals of quartz numerous glass-cavities, testifying to the once fluid condition of the magma from which they were enclosed, whilst the older porphyries are frequently found to contain, in part, similar glass-cavities, and in part, or sometimes exclusively, cavities filled more or less with fluid. The Delft Professor infers that, in these latter hollows, the glassy material has been in process of time decomposed and dissolved out by the percolation of water, and that the porphyries were solidified from a similarly fused magma, although even this paste may have been modified from the glassy condition by slow molecular change.

That the mineral olivine plays a part in the augitic rocks analogous to that of quartz in the porphyries is confirmed by examination of specimens (figured in the series of ten beautiful plates) from Vesuvius and the Siebengebirge; and their numerous glass-cavities point to a similar genetic origin.

The novel and elegant researches of the geological microscopists form a valuable set off-as against the dicta of some of the bolder experimentalists who would deny to nature the power of doing more than they can themselves accomplish in their laboratories, and who, protesting against the possibility of sundry crystallized minerals being produced by fusion, are driven to wild and arbitrary inventions to account for what we see in the Tertiary and modern lavas.

When a sedimentary origin is gravely proposed for basalts and elvan porphyries, geologists know far too well the incompatibility of observed facts with such a proposition to be shaken in their previous convictions; but an examination of the microscopic enclosures of the plutonic rocks further confirms the conclusions of those observers who have examined the seats of modern volcanic action.

Not only may we cite, with full assurance, a list of minerals produced in a crystallized condition from a melted mass, certain kinds associated with certain other kinds in wonderful family likeness of grouping, at points of eruption widely distributed over the globe, but even the higher temperature required for sublimation may with confidence be occasionally called in to explain the presence of some of the crystallized mineral species. The origin of the countless crystals of specular iron (oligist) sparkling around a crater or in the *bocca* of a lateral eruption, can be ascribed to nothing else than the sublimation of the metal as a chloride; and, recently, that high authority Gustav Rose has shown that crystals of augite have been formed by a similar process. Herr von Rath discovered in the irregular fissures of a cinder cone (the great Eiterkopf, near Andernach) crystals of specular iron dotted with minute yellow crystals, which proved to be augite; and the conclusion drawn from

their association was, that these latter had also been formed by the sublimation and subsequent oxidation of chlorine combinations.   It is, perhaps, still doubtful whether we may conclude, with the eminent Berlin Professor, that this discovery rehabilitates the suggestion of Scacchi, who ascribed, years ago, the fine crystallization of numerous silicates of the Vesuvian lavas, such as melanite, sodalite, hornblende, felspar, &c., to sublimation.

Subterranean Temperature.—In connexion with the change of rock masses by metamorphic action, and with the phenomena of volcanic forces, we are constantly reminded of the internal temperature of the globe, and find it difficult to establish any clear view of the causation of either one or the other without being first satisfied of the reality and amount of this internal heat.   Confessedly there are many difficulties in the way of a sufficient knowledge of the character of the interior of the earth, even to a moderate depth; but surely among the main facts upon which we may depend is that of an increase of temperature with increasing depth.   Such is, however, the desire on the part of certain writers to launch their own novelties and to upset the old landmarks, that one has seen this position of late altogether questioned, or an explanation of the increased heat proposed in the compression of the air, the friction caused by the working of mines, and in the warmth of men, the burning of candles, gunpowder, &c. All these are doubtless efficient causes, and in inquiries pretending to accuracy must be either avoided or eliminated; but they have long since been shown to be inadequate to produce the results obtained[*].

Although, as I believe, all actual observers are agreed upon the main point at issue, it is very true that a great uncertainty prevails as to the rate of elevation of temperature met with in descending, whether it be according to a regular scale of progression, increasing *directly* with the depth, or be intermittent, as maintained long ago by Mr. R. W. Fox—whether it increases below a certain horizon in a less rapid ratio, and, after reaching a given depth, again more rapidly—and how much it may vary in the different classes of material which make up the crust of the earth.   These data we doubtless ought to be able to obtain from multiplied careful observations; but the more remote question, viz. the cause of such increase, is far more difficult of solution, and yet need not perhaps for ever baffle the inquiries of man.   A further and growing reason for inquiry into this subject exists in its bearing upon deep-mining operations; and through some of these, completed of late years, we obtain valuable confirmation of the principal facts on which most geologists have long been inclined to rely.

Among accurate researches into the temperature of the earth at great depths, those of M. Walferdin (published in the Comptes Rendus) are well deserving of attention, carried out as they were in a bore-hole deeper than any which had previously been executed. The massive and yet contorted principal seam of coal at Creuzot

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* See the masterly essay of Cordier, in the Mém. de l'Institut, tom. vii., and the papers of R. W. Fox, F.R.S.

(Saône-et-Loire) being thrown down by a dislocation on the east, which brought the strata of the Trias against the coal-measures, M. Schneider, the director of that great establishment, called in the aid of the eminent bore-master Herr Kind ; and at the time of the experiments (in 1856) one bore-hole, that of Torcy, had reached the depth of 595 metres (1951 feet), and had been suspended; whilst another, that of Mouillelonge, was already down 816 metres (2676 feet), and was destined to be much deeper.

Mouillelonge is not quite two miles from Creuzot, and 321 metres (1052 feet) above the level of the sea. The bore-hole was $0^m\cdot30$ in diameter at the top, and $0^m\cdot26$ at the bottom. At 371 metres (1216 feet) it passed from the New Red Sandstone into the Coal-measures, which consist there of alternations of blackish shales and pink sandstones.

The work was temporarily stopped on the 10th May 1856, at 11 A.M.; and in order to guard against error from the heat generated by the percussion of the boring-implements, a considerable time was allowed to elapse, and the slime in the lower part of the bore-hole was, by means of lowering and raising the "sludger," well stirred up into the water over it ; a first experiment was made after 80 hours, and the thermometers were lowered for 16 hours. A second experiment, commenced 102 hours after the cessation of the work, and in which the thermometer remained at the bottom for $16\frac{1}{2}$ hours, gave a very slightly different result, viz. $38°\cdot31$ ($100°\cdot9$ F.).

The other bore-hole, at Torcy, is 310 metres (1016 feet) above the sea. It had been so long abandoned that no error from the friction of working was to be apprehended ; and as the lower part had fallen in, the experiment was made at 554 metres (1817 feet). The result was here $27°\cdot23$ ($81°$ F.), and on a second occasion, ten days afterwards, $27°\cdot22$ C.

The boring, then, at Mouillelonge, compared with that of Torcy, gives for a difference of depth of 262 metres an increase of temperature of $11°\cdot09$ ($19°\cdot9$ F.), or one degree Centigrade for $13\cdot6$ metres (one degree F. for $43\cdot1$ feet.)

The rate of increase from the surface downwards, the mean temperature of Torcy being estimated at $9°\cdot2$ ($48°\cdot5$ F.), is $18°\cdot02$ for 554 metres, or one degree for $30\cdot7$ metres (one degree F. for 56 feet).

These results would appear to give a more rapid ratio of increase between 550 and 800 metres than between the surface and 550 ; and it remained a question whether the effects of percussion in the deeper bore-hole had been entirely eliminated.

I regret not to have been able to find that M. Walferdin continued his observations after the depth of the bore-hole had been increased. That undertaking was, in fact, fruitlessly continued until it had obtained a total depth of 920 metres, or 3017 feet English ; and the impression among the local Engineers, when I visited Creuzot in 1866, was, that the increment had remained much the same, i. e. one degree Centigrade to 30 metres.

By way of comparison, we may be reminded of the elaborate series of observations conducted in our deepest English coal-shaft,

at Dukinfield, by Mr. Fairbairn*, and whence he calculated that from 231 yards to 685 yards deep, or 693 feet to 2055 feet, the bottom of the shaft, the increase was such as to give one degree F. for 76·8 feet. At this rate, the temperature of boiling water will be reached at the depth of $2\frac{1}{2}$ miles from the surface, whilst by the French experiment it would occur at about $1\frac{3}{4}$ mile.

The coal-miners of Belgium, in the exploration of their narrow and highly contorted coal-field, have, within the last few years, sunk some of their pits, especially in the neighbourhood of Charleroi, to depths which, in several instances, exceed the workings of any other part of the world.

I am indebted to the kindness of M. Jules Gernaert, the efficient Inspector-in-Chief under the Belgian Government, for observations recently made in some of these collieries. The recorded temperatures, it will be seen, are those of the air in various portions of the excavations; and some allowance may therefore be made in those parts where the warmth is increased by the presence of men; whilst the down-draught of the ventilating current will be observed to cool, in a great degree, the neighbourhood of the pit.

Colliery of Grand Mambourg, at Montigny.	Temperature.	
	Cent.	Fahr.
Pit Résolu.—Temperature at surface, Dec. 6, 1867	0°·2	
At the depth of 665 metres, 2180 feet	10 ·00	50°
At the end of 40 metres of stone drift	11 ·00	51 ·8
In a level 150 metres long, in the seam	15 ·00	59
At the coal-face, 320 yards from pit	20 ·00	68
In the holing at the face	23 ·00	73 ·4
At bottom of upcast pit, 586 metres, or 1922 feet deep	22 ·50	72 ·5

If we take the mean annual temperature of the district at 10°·6 C., or 51° F., it is clear that, the observations being made when the thermometer at the surface was almost at freezing-point, the temperature of all the workings up to the face of the coal was considerably reduced by the coldness of the in-taken air; and the rate of increase due to the depth can hence only be roughly estimated at one degree F. for from 88 to 117 feet.

Colliery of Bonne Espérance, Montigny.	Temperature.	
	Cent.	Fahr.
Pit St. Augusta, Dec. 7, 1867.—Surface-temperature ...	0°	32°
At depth of 575 metres, or 1886 feet	9 ·50	49
At end of a gallery 60 yards long	11 ·50	52 ·7
At a coal-face, 380 yards from pit........................	19 ·00	66 ·2
In waggon-way, behind a door	21 ·00	69 ·8
At a working to which the air had travelled 930 yards	18 ·00	64 ·4

* British Association Reports 1861, p. 55.

Colliery of the Poirier, Montigny.	Temperature.	
	Cent.	Fahr.
Pits St. André and St. Louis, Dec. 10, 1867. Surface-temperature..	0°	32°
At depth of 672 metres, or 2202·76 feet	14	57 ·2
In a stone-drift, 240 yards from St. André pit.........	22 ·50	72 ·5
In a rise-incline in the seam	24 ·50	76
Return air at bottom of St. Louis pit	20 ·00	68

Colliery of Thévson.	Temperature.	
	Cent.	Fahr.
Temperature at surface	3°·50	38°·30
At depth of 704 metres, or 2309 feet	14 ·00	57 ·2
In the return air	22 ·00	71 ·6

Colliery of Sacrée-Madame, at Pampreny.	Temperature.	
	Cent.	Fahr.
Pit Fond du Pige.—Temperature at surface, Dec. 1867...	3°·50	38°·3
At depth of 562 metres, or 1843 feet	8 ·50	47 ·3
At depth of 602 metres, or 1974 feet....................	9 ·50	49 ·1
At bottom of up-cast shaft................................	17 ·00	62 ·6
Engine-shaft.		
At depth of 424 metres, or 1390 feet	7 ·00	44 ·6
At depth of 634 metres, or 2079	10 ·50	50 ·9
At bottom of up-cast shaft................................	22 ·00	71 ·6

Pit Simon Lambert, at Gilly.	Temperature.	
	Cent.	Fahr.
At depth of 1064 metres, or 3489 feet English	26°·00	78°·8

This latter observation is interesting, as taken at the deepest point to which man has yet penetrated in the crust of the earth; but its correctness is doubted by M. Gernaert; and even if accepted, it can only be held, along with the others above recorded, to verify the general conclusion of the rapid rate at which an in-going current of cold air is heated by contact with the rock surfaces. The result is satisfactory in a technical point of view, as showing the moderate temperature which, by means of active ventilation, may be made to pervade the deep workings; but, for scientific deductions, we must await the series of observations which M. Gernaert proposes to carry out through different seasons of the year.

It is scarcely needful to remind the Fellows of this Society that we are in possession of valuable tables of subterranean temperatures observed in the mines of Cornwall by our associates Mr. R. W. Fox and Mr. W. J. Henwood, and that these gentlemen, with other careful observers of the same class of phenomena, have taken their measurements either from the water issuing from unbroken portions of the rock, or from the rock itself, as tested by a thermometer buried in a bore-hole for at least some hours.　The air of the excavations is necessarily apt to be affected by the causes above referred to, as well as by the heat generated by the men, candles, &c. ; but even observations on the air, besides being interesting with reference to the condition of the work-people, exhibit clearly enough the remarkable progression of temperature in depth, as well as another fact destined to be very important in the working of our deep mines, viz. the gradual effect of the ventilating currents in cooling the surfaces of rock which affect the air.　Amid the other objects of my frequent underground journeys, I have often been led to note, with some care, the observed temperature of particular points at successive depths, and, in many cases, in successive years ; and the following extracts may interest some of our Members by aiding in the confirmation of the above two propositions.

I therefore venture to give the following tables, as showing the temperature of the air in several of our deepest mines, which have unfortunately within these last few years been abandoned to the waters :—

Depth.		Holmbush Copper-mine, Callington, Cornwall.	
In fathoms.	In feet.	16th Oct. 1857.	2nd Sept. 1861.
100	600	Surface— At 10.30 A.M. .... 66°·5	.... 66° Inclined shaft... 72
124	744	At Wall's, western end... 79 Water at do............... 77 South cross cut........... 78	
132	792	End of level, west ...... 83 Pitch in the lead lode... 84	
160	960	West end 84	In inclined shaft 76
175	1050	....	East end .... 84 Do. in rise......... 88 Do. at shaft ...... 82 West end 86

Levant Mine, St. Just, Cornwall.

In fathoms from adit.	In feet from surface.	6th Aug. 1858.	28th May 1859.	Aug. 1860.	16th Sept. 1862.	20th Oct. 1863.
100	720	Surface temp. at 10 A.M. ... 61°·5	.... 65° At shaft .... 68°	.... 62°	.... 65°	.... 59°
130	900	In north lode (close end)...78°		Far in, on N.W. 78°		At shaft.........69° End, on N.W. ...74°
150	1020		In cross-cut north beyond north lode 78°	Between main and north lode ... 71°·5	At shaft .... 69° Cross cut north beyond north lode, 76° North lode (eastern end and stopes) 81°	North lode ......74°
170	1140		In cross cut north (far from air)...81°			New north lode 75°
190	1260	In north lode 81°				19th Oct. 1867.
210	1380					At shaft.........76° North lode (eastern end) ....86°

These observations were made on the route down the engine- or pumping-shaft, and thence to the north and west, under the sea. It may be noted in the above table, that whilst the temperature steadily increases as we descend, at a rate (not accurately deducible among conflicting air-currents, &c.) giving us from 35 to 57 feet of vertical depth for one degree of Fahrenheit, it will be found to differ by as much as 10 degrees at the same level of depth, according to the condition of the ventilation, and yet that a regular diminution of temperature from year to year is observable at the same spot, the ultimate limit of which is somewhat uncertain.

South Hoo Lead-mine, near Callington.

Surface, 30th October 1863, at 9.30 A.M.			50°
215 fathoms level, in south end of lode			79
226	do.	out of the air-current	83
237	do.	behind a pile of stuff, in end	92
250	do.	out of air-current	88·5

The above are, in all the deeper levels, maximum temperatures, increased beyond the normal by want of adequate ventilation.

Fowey Consols Copper-mine, East Cornwall.

Surface at 11 A.M., October 1866			61°
140 fathoms level, on footway lode, far from air-current			86
240 fathoms level, water in cross course			96
270	do.	end near Bothall's shaft	88
280*	do.	do.	89

In the latter inspection I was accompanied by Mr. Kendall, M.P., F.G.S.; and we found that, whilst the remainder of the workings were considerably cooled down in the series of years since they were first laid open, the above points showed exceptionally high temperatures, and the water in the cross course at the 240 fathoms level was so much hotter than it ought, from mere depth, to be, that it might be regarded as a thermal spring.

Lastly, a remarkable instance is offered by the great tin-mine Wheal Vor, near Helston, where, leaving (30th September 1858) a midday temperature of 67° at surface, I descended to the bottom immediately after the water (which had occupied it for many years) had been extracted, and found, at 284 fathoms depth from adit, or 311 fathoms from surface, the air and the water issuing from the rock both at 80° Fahr. The ruinous expense which beset the resumption of this old work occasioned its very soon being again closed; but it was curious and somewhat unexpected to find the temperature no higher at the 284 fathoms level than it was recorded at 240 fathoms twenty years before by Mr. W. J. Henwood; and the explanation is probably to be found in the sea of surface-water which had for a long time before my visit occupied the excavations as well as the joints and fissures of the rock around them, and was still pouring down on all sides of the great open stopes of the bottom of the mine. Observations made a few months afterwards by Capt. Francis, and published by Mr. Henwood, state that different parts of the same deep level then showed temperatures of from 82° to 90°. It was quite evident that, as usual, what was at one time the bottom of the mine, had become cooler when, after a series of years, other workings had been opened beneath it; but, as Mr. Henwood insists, the same locality still maintained a higher temperature than the mean of the shallower parts of the mine. And I am inclined to think that the actual bottom at the time of my visit may have suffered refrigeration by the rock parting with its heat to the currents of cold water

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* To give the absolute depth from surface at the shaft, 40 fathoms may be added to the nominal depth of each level, the adit being at that depth from the mouth of the shaft.

which, whilst the whole excavation was drowned, would naturally descend to its deepest parts.

To resume. A number of anomalies and irregularities obtrude themselves among the effects of the terrestrial temperature which, although they throw no sort of doubt upon the doctrine of its progressive increase, by no means tally with the deductions of theory and physical experiments. Our lamented former President, Mr. Hopkins, established, by direct experiment, the fact of certain rock-substances, such as the denser limestones, granites, and syenites, having a conducting-power (for heat) of twice, thrice, or four times that possessed by the less dense materials, chalk, clay, and sand-stone, and that the conduction of heat is very sensibly affected, although not to any great amount, by discontinuity in the conducting mass. From these data theory would infer that, if the conductive power of a certain rock be double that of another, the increase of depth corresponding to a given increase of heat would in the former case be double of what it is in the latter. Hence in fact Hopkins himself admitted that, the conductive power of the strata of the Paris basin being only about half that of the Coal-measures, the rate of increase of temperature in the Artesian well of Grenelle ought, according to his theory, to be nearly twice that of the pit of Dukinfield in Cheshire, whereas, from the observations made at that time, down to the depth of 1330 feet, the disparity in the two cases appeared to be very slight. The further prosecution of the shaft, however, gave a nearer approximation to the theoretical result, in showing 76·8 feet to 1° Fahr. as against 60 feet at Grenelle[*].

It cannot but be admitted that, however much the observations made by the small cohort of accurate observers may show varying rates, their uniformity is more remarkable than their divergence, and this with a great disregard to the nature of the masses, which, as regards their quality, are shown by experiment to possess very different degrees of conductive power. Mr. Hopkins, in order to explain the anomaly, tests the problem of a deep isothermal surface being in a position not parallel with the exterior of the globe, but allows that there are no conceivable grounds for the admissibility of this very limited hypothesis according to the theory of central heat. But, on the other hand, Cordier showed, in 1827, that the rate of augmentation of temperature in the same class of rocks (the Coal-measures) of neighbouring departments of France is in one case double, in another nearly treble that of a third; and from these apparently imperfect data he inferred that the subterranean heat is distributed with much irregularity in different districts. On review-

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[*] A remarkably slow rate of progression is shown, as I am informed by Mr. W. J. Henwood, F.R.S., at the celebrated gold-mine of Morro Velho, in Brazil, situate at a height of 3250 feet above the sea, and opened in clay-slate rock. The water issuing from the rock at 45 fathoms depth, observed in 1843, had a temperature of 69°, that at the bottom of the mine in 1863 and 1864, at 145 and 155 fathoms deep, 72°. These temperatures were quite independent of the effects of the warm rains a little before and after Christmas, which make themselves felt all the way down the engine-shafts. The rate of increase would hence be but one degree for 200 feet.

ing the whole subject, Mr. Hopkins was led to the conclusion that the existence of a central heat is not in itself sufficient to account for the phenomena which terrestrial temperatures present to us.

Are we, upon these grounds, to look to various scattered foci of heat within the thickness of the earth's crust? How, unless we have the sources of lava and of high-pressure steam at a moderate distance beneath the surface, is it possible to explain the action of volcanos, and the undulation and contortion of the strata, whether through elevation or, more generally, through depression? how, with a crust hundreds of miles thick, or with a dense and solid globe as upheld by Poisson and his followers, conceive of the phenomena which mark the presence of mountain-chains around the whole earth? And if there be but a crust, whether overlying a liquid nucleus or limited seas of molten rock, is it probable that the thickness will at different places vary within wide limits? I cannot but think that we have much more to learn before the problem is ripe for solution. Prof. Phillips well showed, some years ago, that sundry conditions must be taken into consideration beyond the mere conducting-power of rock-masses, and that *convection*, or transmission by means of water and air, plays at the present time the more important part. In our copper-mines the chemical action of the sulphide ores manifestly gives rise to an abnormal temperature; at equal depths the air and rock of tin- and of lead-veins are cooler. And, in juxtaposed mines, the same horizon shows so different a temperature, according to whether they be opened in granite or in clay-slate, that we look upon the cooler condition and slower rate of increase of temperature in the unstratified rock as somewhat in accordance with the result of Hopkins's experiments. Yet, on taking into account the frequent alternation of these rocks within a small area, and, more than all, on carrying our mental view downwards a few thousand feet from the surface, and speculating on the small part which must be played in depth by the stratified substances, we are obliged to conclude that far more complete observation is greatly needed.

Geology has happily in the meanwhile an abundance of other and more accessible problems for our study; and, notwithstanding the difficulty (at first sight almost insurmountable) of exploring the nature of the globe far beneath where we can ever hope to penetrate, marvels have already been accomplished in that direction. Not only the actual presence, but the gradual history of the construction, of miles on miles in thickness of parts of the crust have been so far established that we may well afford to await the gradual development of the physical and chemical inquiries by aid of which many of these researches can alone be pursued.

And now, gentlemen, in approaching the end of my task, I feel perfectly conscious that I have touched only on the one side of our great subject of geological science, and have almost omitted to mention the other. This has not been for want of due consideration. I reflected that a mass of palæontological details imperfectly arranged and set before you could profit little, and that I should best fulfil

my office, first, by dwelling on matters with which I had a surer acquaintance, and, next, by endeavouring to provide you with a successor to this chair who would do full justice to what I had pretermitted.   You have elected that successor, a master in his vocation ; and we shall now, during his term of presidency, have full justice done to the biological portion of our science.

For myself, I have to express to the Society my gratitude for the honour which they have done me in placing me in the enviable position of presiding over their interests for the past two years, and to the Officers and Members of Council my best thanks for the unvarying readiness and courtesy with which they have assisted in all our deliberations ; and I may be permitted to record my confident expectation that, whilst we are all agreed in the great objects of our studies, differences of view and of mode of inquiry may occur on moot points and yet the same good feeling and friendly bearing which have always hitherto distinguished our body will long continue to adorn its future progress.

The efforts of geologists must, indeed, be more or less as the incidents in a voyage of discovery.   We know that the region of perfect truth, for which we yearn and seek, lies looming ahead of us ; but as yet we have enjoyed only dim glimpses of its form, although some few successful navigators have here and there been fortunate enough, after years of persevering toil, to fix with accuracy the position of an islet or a promontory.   But the region we make for is one of vast extent ; and we sail on various courses and in very different varieties of craft.   Some of us push rapidly forward in fast clippers ; others cleave their way slowly, and yet not always surely. And the past history of our voyage proves the importance of an occasional crucial observation, by which to determine whether we have not, in despite of strenuous efforts, been making leeway, or even been carried completely off our course by currents of which we had no cognizance.

Possibly it may never be vouchsafed to mankind to survey in its full length and breadth that glorious land of which we are in quest ; but of this we may feel assured, that amid the thousand difficulties and the thousand experiences of the laborious undertaking, much must accrue that will strengthen and elevate the explorers, much that will tend to promote the material advantage and the moral dignity of our species.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

November 6, 1867.

Nathaniel Plant, Esq., De Montfort House, Leicester; Colonel Lane Fox, F.S.A., late Grenadier Guards; G. H. F. Ulrich, Esq., of the Geological Survey of Victoria, Melbourne; Rev. J. J. Bleasdale, D.D., Melbourne, Victoria; J. Ince, Esq., 26 St. George's Place, Hyde Park Corner, S.W.; and the Rev. T. S. Woollaston, M.A., Exford, Devonshire, were elected Fellows.

The following communication was read:—

On the Amiens Gravel. By A. Tylor, Esq., F.L.S., F.G.S.

[The publication of this paper is unavoidably deferred.]

(Abstract.)

The author refers first to the prevalent views respecting the gravels of the Valley of the Somme, namely:—(1) that there are two deposits of distinct age—the upper and the lower valley-gravels; (2) that the former of these is the older; (3) that the Valley of the Somme has been excavated to the depth of 40 or 50 feet since its deposition; (4) that both gravels contain bones of extinct animals, and implements of human manufacture, the lower gravels, however, containing the greater number of species of Mollusca, and the upper the greater number of flint implements; and (5) that the height (70 feet) of the gravels at St. Acheul above the present level of the Somme is much beyond the limit of floods, and that, therefore, they could only have been deposited before the river-channel was cut down to its

present level. He then points out that the general effect of these views is to refer back the remains of man found at St. Acheul to an indefinite date, separated from the historical period by an interval during which the valley was excavated.

In former papers Mr. Tylor stated his belief that the upper and lower valley-gravels of the Somme are continuous and of the same age, which he considered to be close to the historical period. In this paper he states facts which appear to him to demonstrate the truth of his views, and describes a number of sections near Amiens, in which the levels were laid down from an exhaustive survey by M. Guillom, Chief Engineer of the Northern Railway of France.

The conclusions he has thus been able to arrive at are the following :—(1) That the surface of the chalk in the Valley of the Somme had assumed its present form prior to the deposition of any of the gravel or loess now to be seen there ; (2) that the whole of the Amiens valley-gravel is of one formation, of similar mineral character, contains nearly similar organic remains, and belongs to a date not much antecedent to the historical period ; (3) that the gravel in the valley of the Somme at Amiens is partly composed of débris brought down by the river Somme and by the two rivers the Celle and the Arve, and partly of material from the higher grounds washed in by land-floods ; (4) that the Quaternary gravels of the Somme are not separated into two divisions by an escarpment of chalk parallel to the river, as has been stated ; (5) that the evidence of river-floods extending to a height of at least 80 feet above the present level of the Somme is perfectly proved by the gradual slope and continuity of the gravels deposited by them ; and (6) that many of the Quaternary deposits in all countries, clearly posterior to the formation of the valleys in which they lie, are of such great dimensions and elevation that they indicate a pluvial period just as clearly as the Northern Drift indicates a glacial. This Pluvial period must have immediately preceded the true Historical period.

November 20, 1867.

Sir George William Denys, Bart., Easton Neston, Northamptonshire, and Septimus P. Moore, Esq., LL.B., 5 St. John's Park Villas, Haverstock Hill, N.W., were elected Fellows.

The following communications were read :—

1. *On the* Glacial *and* Postglacial Structure *of* Lincolnshire *and* South-East Yorkshire. By S. V. Wood, Jun., Esq., F.G.S., and the Rev. J. L. Rome, F.G.S.

[The publication of this paper is unavoidably postponed.]

(Abstract.)

The features of Yorkshire and North-east Lincolnshire having distinctive characters from those of Central and South Lincolnshire, the authors describe the two areas separately. In the former, their

coast-sections exhibit the Glacial clay separated into two portions: of these the lower, which they identify with the ordinary (or upper) Glacial clay of the South, contains abundant chalk débris; but the upper or purple portion (which was in places divided from the lower by sand and gravel beds) contains no chalk in the upper, and but little in the lower part of it, the place of the chalk being taken by fragments of Palæozoic rocks. The latter of these clays alone extends over the Wold-top at Speeton, and alone occupies the valley along the northern Wold-foot, and so away northwards to Scarborough and the Tees-mouth, from which the authors infer that the north of England did not subside beneath the glacial sea until after the south had been submerged. The so-called Bridlington " Crag " is shown to be an intercalated bed in this purple clay. Both these clays are shown to be denuded, and their denuded edges to be everywhere covered by a much thinner Boulder-clay, that of Hessle, which wraps Holderness like a cloth, extending to altitudes of 150 feet, and running down the east of Lincolnshire to the Fen-border. This Postglacial Boulder-clay of Hessle is again cut through, and in those places covered by posterior beds of gravel, one of which (at Hornsea) contains fluviatile shells. At Hull this clay supports a forest, which is now submerged 33 feet below the Humber,—the same submerged forest also occurring at Grimsby. The authors regard the position of the sea during the Postglacial period as having been principally on the west of the Yorkshire and North Lincolnshire Wold until the formation of the gravel-troughs cutting through the Hessle clay, and that its present position was connected with a recent westerly elevation and easterly depression.

The Glacial clay of Central and South Lincolnshire belongs to the chalky portion, from which all the superior or purple part of the formation has been denuded; and the valleys of Central Lincolnshire are shown to be cut out of the Cretaceous series and Glacial clay as a common bed, the hills formed of the clay rising to elevations equal to the Wold in that part.

The Glacial clay of both areas is shown to be denuded westwards, and the denuded edges occupied with sands and gravels termed by the authors denudation-beds.

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2. On Supposed Glacial Markings in the Valley of the Exe, North Devon. By N. Whitley, Esq.

(Communicated by the Assistant-Secretary.)

In a late paper on the grouping of the rocks of North Devon, Professor Jukes mentions some glacial grooves observed by him in the valley of the Exe. The interest attached to this subject in such a country induced me to visit the spot; and in driving down the valley I found the " grooved " rocks about half a mile above Barlynch Abbey, and on the north face of a projecting tongue of hard purple grits. Two separate portions of the rock were deeply indented; and the long straight furrows, like a bold cornice of a

room, might, on a hasty view, be set down as large glacial striæ; a nearer inspection, however, soon dispels this opinion.

1. The "grooves" (I use the term for convenience) are not parallel to the bottom of the valley down which the glacier was supposed to slide, nor do they on the two pieces of rock run in the same direction (fig. 1).

Fig. 1.

2. The "grooves" may be traced into, and under, a portion of the overlying rock; and it becomes obvious that they were exposed, not by the action of ice grinding down the overlying rock, but by the tool of the workman removing the rock above in order to form the new road cut as a bench along the steep hillside.

3. The cross section of the beds, of which I give an enlarged sketch (fig. 2), shows that the "grooves" are formed by the minor

Fig. 2.
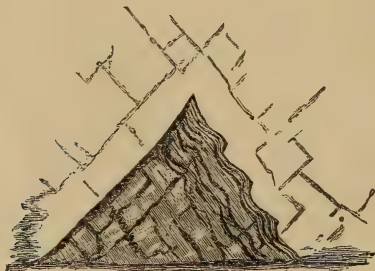
folds of the strata; and the lamination of the interior of the rock is bent so as to correspond with the "grooves" on the surface.

The evidence, therefore, appears to be conclusive—that the "grooves" have been formed by the minor contortions of the strata, and not by glacial action.

3. *On* DISTURBANCE *of the* LEVEL *of the* LAND *near* YOUGHAL, *on the* SOUTH COAST *of* IRELAND. By A. B. WYNNE, Esq., F.G.S., of the Geological Survey of India.

[Abridged.]

THE region which has undergone recent disturbance in the neighbourhood of Youghal is a part of that referred to in Prof. Jukes's able paper read before the Geological Society "Upon the Mode of Formation of some of the River-Valleys in the South of Ireland" (see Quart. Journ. Geol. Soc. vol. xviii. p. 378, 1862) with a map,

to which I refer more particularly, as upon it Youghal Bay, at the mouth of the river Blackwater, will be found marked.

In this paper (p. 398) is the following :—" The South of Ireland, however, seems to have been exposed as dry land ever since the close of the Palæozoic epoch, with the single exception of the depression which it suffered beneath the sea during the Pleistocene or Glacial period." To some time during this Glacial period, there-fore, evidences of disturbance of level might be referred if they consisted of nothing more than the usual phenomena connected with the Glacial Drift. It will be seen, however, from what follows, that considerable alterations of level have taken place along the coast of Youghal Bay subsequently to the formation of the recent peat which so commonly covers the Glacial Drift of Ireland.

The occurrence of submerged peat beneath Youghal Strand is mentioned at some length by Dr. Charles Smith in his ' History of Cork,' 1749, book ii. chap. 1, where it is recorded that " good turf is dug every season, and also great quantities of timber trees, as fir, hazel, &c.," from beneath the strand, and that the bog extends as far as the lowest ebbs uncover it, and probably much further.

He says also that, about eighteen years before he wrote, the strand was entirely divested of all its sand and gravel, and, being left quite bare, great quantities of roots of various trees were exposed— that the sea has encroached, and is likely to gain more ground, as the land within the strand lies low and flat ; and he cites several facts to show that the sea was then encroaching on the land [*].

With regard to the submerged bay, the statements of Dr. Smith seem to be correct, as far as can be now seen or learned ; but the foundations of the mill of which he speaks are not at present known.

The strand may be said to commence at the very mouth of the harbour, where, close to the rocks of the western side of the gorge, just below a place called " Moll Goggin's Corner," peat may be frequently seen stripped of the sand at low water [†].

Looking from this place to the south-west, the strand and beach thrown up by the sea are seen to trend from the observer in the direction of the hill called Clay Castle, about half an English mile distant, and beyond it by a slight protuberance in the shore-line, called the Breakwaters (from some wooden constructions placed there to check the wasting of the land), and so on by the mouth of the Fanisk (or Pillmore) stream to the high land of Knockadoon Head. On the landward side of the beach the low ground is covered with peat : and people still alive remember turf being cut where a range of new houses, called " The Strand " or Lewisville, and the railway-station, just behind the beach, are now situated. The water from

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[*] A rude engraving representing a view of the town of Youghal from the Waterford side of the harbour, is given by Dr. Smith, which, save in the form of the ground and the positions of a few buildings, but slightly resembles the place as it is at present.

[†] For some remarks upon this peat, and its bearing upon the denudation of the cliffs close by, see a paper by the author (Geol. Mag. vol. iv. p. 8, 1867).

this low boggy ground is conveyed through the beach by the usual contrivance of tidal floodgates or sluices; so there is reason to believe that the peat on land and that beneath the bay are at the same level, and connected under the beach, and that the sea, by throwing the latter up, has banked itself out from a considerable portion of the low ground.

The part of this beach between Clay Castle and Youghal is stated by residents in the latter place to have been, a few years ago, composed of larger boulders, and so much higher than at present that persons walking behind it could not see the breakers washing its seaward side, and that it has been reduced by the action of the sea.

The eminence called Clay Castle appears, from the Ordnance Map, to have an elevation of 91 feet. It rises gradually from the beach on the north-east side, more abruptly on the south-west and north-west, while on the seaward side it presents a cliff partly vertical or very steep, and partly sloping at the angles usual for the incoherent materials of which it is composed—namely, sandy clay, sand, coarse gravel, and pebbly beds, mingled with some tenacious clay, and occasionally cemented by carbonate of lime, or, in short, such local materials as characterize many parts of the Glacial Drift. It is rudely stratified, the layers being approximately horizontal, and the more clayey and sandy beds nearest to the base; at the south-west end of the cliff the continuation of the beds is interrupted by the outline of the hill, to which they do not here conform, except an uppermost light loamy layer, which seems to form the surface everywhere. From its summit, at the edge of the cliff, it declines inland, and presents no peculiarity of form different from any of the similar-looking mounds of Glacial Drift in this country, except its being cut off to seaward so as to form a cliff. It was once considerably higher, as it formerly extended further seaward with the same outline. Dr. Smith speaks of it as a promontory; but it has now nothing of this form, being cut off by the straight coast-line at its foot.

On careful examination of its materials, it is found to contain fragments and pebbles of the local rocks, with many weathered flints, presenting all the appearance of chalk-flints*, and difficult to refer to the veinstones or hornstones of local rocks—though chalk with flints does not occur *in situ* within great distances, and it can hardly be supposed that these flints came into their present situation in the strata of the hill through human agency in the form of ships' ballast.

The stratified drift-like appearance of these deposits might lead any one to set them down as such; but close search shows that, unlike the generality of Irish Glacial Drift, or any which it has befallen me to explore†, the strata of the hill contain

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* Although a very large number of these flints have been broken and closely examined, not one was found to contain a fossil, or the fragment of one, which would fix their age.

† I am aware that such shells and fragments have been found in a few localities in the drift of Ireland; but, having for years searched every gravel-

sea-shells and their fragments, from the base nearly to the very top, generally white, much worn, and of an aged appearance (including Whelk, Mussel, *Trochus, Cardium, Patella, Venus*, &c.). Some fragments of wood, in the form of charcoal, were found in one spot lying together, near the top of the cliff; and the uppermost stratum of the hill contains numerous land-shells (*Helix* &c.).

Although there are no exposures of peat beneath the sand immediately at the foot of Clay-Castle Hill, from which place it might, indeed, have been washed away, and whether the hill-strata are to be supposed contemporaneous with the rest of the beach or not, it is nevertheless shown by the foregoing remarks to be a raised beach; so that we have here evidence both of elevation and depression, which seem to have taken place in the manner which will be now suggested.

At some time (about the close of the Glacial period, perhaps) the sea was further from the present land than it is now; or otherwise the land in this neighbourhood had a greater elevation, and the low ground of the Castlemartyr valley sloped gently further out to the seaward, being covered by an accumulation of peat where forest-trees had grown. The land became depressed—it may be, generally, as such evidences are common round the shores of Ireland as well as of parts of England; but, whether generally or locally, the land here sank to a depth of more than 90, perhaps 100 feet, or even more.

Subsequently to this depression of 90, 100, or more feet, the land rose again, but not to its former level, though it may have nearly reached this; for a great portion of the boggy strand at the western side of Youghal Bay is never more than a few feet below low-water mark.

At present, and for years past, the land seems to have been subjected only to erosive action by the sea. Claycastle Cliff is being rapidly reduced by atmospheric agencies; and in dry weather streams of sand, greatly increased by wind, may be seen running down its face, so that in a few years hence the cliff may disappear; but I have found nothing to show that the erosive action of the sea is at present being assisted by another downward movement of the land.

Dr. Smith, in his history above alluded to, mentions some islands at Ballycotton Head, a few miles south-west of this place, but does not notice the existence of the larger islet called Capel or Cable Island, off the Point of Knockadoon, supposed to be the Ring Point named by him, as there is a place called Ring in its vicinity—though something in its locality, without a name, is indicated, on his map of the Co. of Cork, as existing in the year 1750. Traditions in the country declare this Capel or Cable Island to have been but recently separated from the mainland.

At a little distance from Claycastle Hill, on the landward side, is a rounded elevation of less height, the base of which has been

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pit I met with in the centre and south of Ireland without ever finding a trace of a sea-shell or fragment of one, I am led to place the cases in contrast.

partly cut through in making the Railway from Cork. The slopes of the cutting are now dressed and grown over with grass; but it may be seen that the banks are mainly formed of sand (with some gravel), precisely similar to some of the lowest deposits of Clay Castle; and numerous white, worn, old-looking fragments of sea-shells may be observed lying on the slopes or slightly imbedded in them; but while there is nothing to the contrary, the evidence of these fragments being *in situ* is hardly so satisfactory as that afforded by the former locality.

The Old Red Sandstone ground to the north of this is high, rather flat-topped, with abruptly sloping sides and occasional small ravines; but this abruptness of its lower slopes is all the appearance which can be taken to suggest the remains of old sea-cliffs.

POSTSCRIPT.—Since the foregoing paper was written, a reply has been received regarding specimens of the flints alluded to, which were submitted to one of the officers of the Geological Survey of England, well qualified to form an opinion about them from his long acquaintance with chalk-districts. He agrees in regarding them as chalk-flints, thinking, from their weathered appearance, that they have been long separated from it. They were first observed by me several years ago, in what I then considered the " drift," along this coast to the east of Youghal, near Whiting Bay. If they are really chalk-flints, are they relics of the denudation which separated England from France?—A. B. W.

DECEMBER 4, 1867.

Henry Palfrey Stephenson, Esq., M.I.C.E., 15 Abingdon Street, Westminster; John Dalman Orchard, Esq., Teighmohr, Sandford Road, Cheltenham; Ezekiel Williamson, Esq., 6 Goodier's Lane, Regent's Road, Salford; William Carruthers, Esq., F.L.S., Department of Botany, British Museum, and 25 Wellington Street, Islington, N.; Thomas Parton, Esq., Mining Engineer, Willenhall, Wolverhampton; Herbert Kirkhouse, Esq., Aberdare, South Wales; Charles Evans, Esq., 3 Devonshire Hill, Hampstead; John Burham Safford, Esq., Stow-on-the-Wold; Major Edward Owen Leggatt, Staff Corps; and Archibald Hamilton, Esq., South Barrow, Bromley, Kent, were elected Fellows.

The following communications were read:—

1. *On the* GRAPTOLITES *of the* SKIDDAW SERIES.
By HENRY ALLEYNE NICHOLSON, D.Sc., M.B., F.G.S. &c.

[The publication of this paper is unavoidably postponed.]

(Abstract.)

THE author first describes the geological relations and distribution of the Skiddaw Slates, and notices their correspondence with the Quebec Group of Canada, and then gives a description of the Grap-

tolites found in these rocks. The genera and their distinguishing characters are the following:—

1. *Dichograpsus*, Salter (3 species): possesses a frond, repeatedly dichotomous from a basal stipe into eight, sixteen, or more branches, each with a single row of cells, the lower part of the stipe being enveloped in a corneous cup.

2. *Tetragrapsus*, Salter (3 species): possesses a frond composed of four simple stipes, arising from a non-celluliferous funicle, which bifurcates at both ends.

3. *Phyllograpsus*, Hall (2 species): differs from the last in possessing a frond composed of four simple stipes united back to back by their solid axes.

4. *Didymograpsus*, M‘Coy (7 species): the frond consists of two simple stipes springing from a mucronate radicle, which may be rudimentary or apparently absent.

5. *Diplograpsus*, M‘Coy (4 species): two simple stipes, united by their solid axes into a celluliferous frond furnished with a radicle at the base.

6. *Graptolites* vel *Graptolithus*, Linn. (4 species): consists of a simple stipe, with a single row of cells on one side, and a small, generally curved, radicle at the base.

7. *Pleurograpsus*, Nicholson (1 species): celluliferous branches derived from a main celluliferous rhachis.

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2. *On the* FOSSIL CORALS (Madreporaria) *of the* WEST-INDIAN ISLANDS. By P. MARTIN DUNCAN, M.B. Lond., Sec. G.S.

Part IV. CONCLUSION.

[PLATES I. & II.]

CONTENTS.

1. *Introduction.*—The descriptions of the Fossil Corals of the West-Indian Islands which have appeared in the Society's Journal since 1862, appear to have interested many geologists residing in the islands; and lately the great desideratum, a collection of specimens from the Tertiaries of Trinidad, has been sent to me by the Rev. Mr.

Eckel. The study of this collection completes that of the Fossil Corals of the West-Indian Islands, so far as I am concerned; and I have therefore added to the description of the new species some corrections of errors which had been made through inexperience; and the synonymy of the species has been appended also.

The tabular statements will be found to prove that the alliances of the Miocene West-Indian Coral-fauna are as they were stated to be in my first communication in 1862.

The additions to the Coral-faunæ of San Domingo, Jamaica, and Antigua, which are recorded in this communication, are interesting; for the Eocene facies of the Jamaican early Tertiary corals becomes more decided, and the Miocene affinities of the San Domingan and Antiguan series are extended. The commonest of the *Heliastræœ* of the Antiguan marl* has been discovered in the Miocene deposit at Madeira; and this relic of the former coral-sea brings the Faluns and the Spanish Tertiaries all the nearer to the Caribbean. Professor Reuss† has enabled me to recognize a species from the Miocene of Java among the Antiguan collection in the British Museum, and he states that a tabulate Coral, a *Pocillopora*‡ from Java, is closely allied to the form described from the Nivaje Shale of San Domingo.

2. *Sketch of the Geology of Trinidad.*—Trinidad does not appear to have the succession of its strata so grandly simple as Jamaica; and its continental relations are distinct and evident. In Jamaica the metamorphosed and igneous rocks form the base of the stratified series (in the typical section§), and the lowest strata are limestones, whose fossils are principally Hippurites and Madreporaria. The Eocene conglomerates and shales succeed, and are covered with the shales, sands, and marls which yielded the corals described in 1864. These Miocene strata are covered, in some places conformably, and in others unconformably, by a great white limestone, through which granite is intruded. There are no beds indicating luxuriant vegetation amongst these Miocene strata, nor have any freshwater deposits been described. From the simplicity of the formation of Jamaica, it is to be regretted that it was not surveyed before Trinidad. The opinion that Trinidad would be a typical island, and that the Antilles generally could be compared with it, was incorrect; and the deficiency of a good trigonometrical survey, of natural sections, and of organic remains has rendered the laborious survey of Wall and Sawkins‖ more interesting in an economic than in a purely scientific sense.

The nomenclature adopted in the description of the geology of Trinidad is of no value when the other islands are considered, but it refers admirably to the mainland.

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* *Heliastræa crassolamellata*, Duncan, var. *pulchella.*

† 'Ueber fossile Korallen von der Insel Java,' 1867. The species is *Favoidea Junghuhni*, Reuss.

‡ *Pocillopora Jenkinsi*, Reuss. I believe it to be a variety of my *Pocillopora crassoramosa*, from San Domingo.

§ Duncan and Wall, Quart. Journ. Geol. Soc. vol. xxi. p. 1: see section through Upper Clarendon, p. 4.

‖ "Report on the Geology of Trinidad," by Wall and Sawkins—a painstaking book, proving the difficulties of colonial work.

There are very few solid data upon which the age of the Trinidad deposits can rest; but Mr. Etheridge long since[*] distinguished the Midtertiary facies of some shells; and Mr. Guppy lately[†] has satisfactorily correlated the deposit whence they came with the Miocene deposits of the northerly islands. The Miocene beds[‡], in which the fossils occur, rest conformably upon highly inclined indurated clays, coarse-grained sandstones, and compact limestones of Cretaceous age. This Cretaceous series is said to be of Neocomian age, and is therefore not to be referred to the same date as the Jamaican Cretaceous series. Wall and Sawkins named the Trinidad Cretaceous series the " Older Parian :" it stretches very nearly midway across the island from west to east; and the Tertiary deposits flank it to the north, south, and east. There is an outlier of the Older Parian in the south of the island; and in a synclinal trough a part of the Naparima series (the fossiliferous Miocene) rests immediately upon the Cretaceous rock. But, although in contact in the south, there is a band of clays, shales, and yellowish limestones (the Nariva series) which separates the two series in the middle of the island.

The fossiliferous deposit at St. Croix, near Savanna Grande, whence the fossil Corals were derived, is in the portion of the Naparima series which is separated from the Cretaceous strata by the Nariva series. On the northern side of the Older Parian rocks this Nariva series is not repeated; but a limestone, massive or granular, and often crystalline in its character, succeeds at once. Like the Naparima series, it is fossiliferous; but there are no satisfactory data, only extreme probability, to prove that this Tamana series is to be corelated with the Nariva or the Naparima deposits. There is a great mass of deposits resting on these limestones of the Tamana series, and occasionally on the Older Parian rocks, and stretching away to the north; they are often rendered highly carbonaceous by lignites, and are more recent than the Tamana limestones.

Corresponding with these carbonaceous deposits of the north, there is a great arenaceous series in the south which rests upon the Naparima deposits. The porcellanites, lignites, and natural asphalts of this southern representative of the carbonaceous northern series are the best-known peculiarities of Trinitatian geology.

The Miocene of Trinidad appears thus under different mineralogical conditions on the north and south of the Cretaceous series. A limestone and a lignitiferous series exist to the north; and a yellow limestone, clays and shales, fossiliferous marls, and an arenaceous and lignitiferous series are found to the south of the Cretaceous rocks. There is apparently no trace of a chalk of the Hippurite age, nor is there anything like the Eocene shales of Jamaica.

The geological structure of the island is moreover complicated by the range of hills which form the north coast, and whose detritus covers up the northern extremity of the lignitiferous series. This range is, probably, geologically the same as the littoral chain of

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* In " Report of Geology of Trinidad," p. 164.
† J. L. Guppy, Quart. Journ. Geol. Soc. vol. xxii. p. 281 *et seq.*
‡ Wall and Sawkins, *op. cit.* note 5.

Venezuela; it consists of mica-slates, quartzose slates, shales, and sandstones &c., greatly contorted to the north and south, and dipping very generally to the south in the central part of the mass. Its age is unknown; and its connexion with the Tertiary series does not appear to be made out satisfactorily.

The fossiliferous deposit at St. Croix is in the same series as the cliffs at San Fernando described by Mr. Guppy; and that author decides that the alliances of the fossils from the limestones of San Fernando are closer with those from the Jamaican Miocene than with those of the Chert of Antigua. But the corals found in the same series as the San-Fernando Limestones (the Naparima Marl), which are about to be described, are closely allied to those of the Chert and Marl of Antigua and the Nivajé shale of San Domingo. The majority of the Jamaican corals belong to species which indicate deep water; but those of Trinidad are reef species; so that the essentials for comparison hardly exist*. Nevertheless there is a sufficient community of species to correlate the Trinitatian Miocene with all the coralliferous deposits which have been described in the various islands in a wide sense; but it is impossible to assign a correct order of succession.

Certainly the Trinidad deposits which yield the Corals are not of greater age than the Nivajé Shale, the coralliferous beds of Vere, in Jamaica, and the Antiguan Chert and Marl; and there are no data by which a Lower, Middle, and Upper Miocene may be established in the Caribbean area so as to correspond with the divisions of the European Miocene.

3. *List of the Species of Fossil Corals from St. Croix, Trinidad.*—

1. Heliastræa endothecata, *Dunc.*
2. —— cylindrica, *Dunc.*
3. —— Barbadensis, *Dunc.*
4. —— cavernosa, *Esper,* sp.†
5. ——- altissima, sp. nov.
6. Brachyphyllia Eckeli, sp. nov.
7. —— irregularis, sp. nov.
8. Astræa Pariana, sp. nov.
9. Isastræa confusa, sp. nov.
10. Stylophora raristella, *Defrance,* sp.‡
11. Stylophora minuta, sp. nov.
12. —— mirabilis, *Michelotti et Duchassaing* †.
13. Stephanocœnia intersepta, *Esper,* sp.†§.
14. Agaricia agaricites, *Lamarck*†.
15. —— undata, *Lamarck*†.
16. Porites Collegniana, *Mich.*‡
17. —— astroides, *Lamarck*†.
18. Alveopora Dædalæa, *Blainville* §.

4. *Descriptions of the new Species from Trinidad.*—

HELIASTRÆA ALTISSIMA, spec. nov.   Plate II. fig. 3.

The corallum is very massive and tall, and its upper surface is subplane and wider than the base. The calices are barely above the common surface, they are circular, but occasionally deformed, and they are slightly unequal in size. The calicular fossa is shallow, and the calicular margins are broader than the septa. The columella

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* Duncan, "West-Indian Fossil Corals," Quart. Journ. Geol. Soc. Nov. 1863, and Feb. 1864; and Duncan and Wall, Quart. Journ. Geol. Soc. Nov. 1864.
† Species of the present West-Indian Coral-fauna.
‡ Species of the European Miocene deposits.
§ Species of the present Pacific Coral-fauna. .

is small, distinct, lax, and parietal. The costæ are well marked, unequal, and rarely touch, and they are thicker than the septa. The costæ of the highest order are well developed, and contrast with their rudimentary septa. The septa are delicate, they are thinner midway than elsewhere, and those which reach the columella have a paliform tooth ; they are not exsert, and are only slightly dentate. The septa are very irregular in their arrangement. There are six systems, and in most of them there are three cycles with or without a part of a fourth in one-half of the system, so that there are constantly six septa in a system instead of eight. The endotheca is well developed ; and the dissepiments are close, stout, and nearly horizontally parallel. The exotheca is abundant, forming small cells with arched outlines. Height of corallum 6–8 inches. Diameter of calices $\frac{2}{10}$ inch.

Locality. St. Croix, Trinidad.

BRACHYPHYLLIA ECKELI, spec. nov.   Plate II. fig. 4.

The corallum is large, massive, and irregular. The corallites are cylindrical, of various lengths, and are not always parallel, neither are they equidistant ; they are not free, but their calices are more or less continuous by means of the costæ. The walls are stout and independent. The calices are large, and are of various depths, and they do not rise as truncated cones ; but their interspaces are broad, convex, and are traversed by the more or less continuous costæ. The columella is small, spongy, and prominent. The septa are numerous, unequal, and crowded ; they are thicker at the wall than elsewhere, are barely exsert, and are faintly dentate. They are usually forty-eight in number. There are six systems and four cycles, and some orders of the fifth sometimes exist. The doubly laminar condition of the septa is very distinct. Most of the septa join the columella, and those of the fourth and fifth orders frequently curve towards the larger septa. The costæ of the principal septa, and often those of the others, touch or unite to the corresponding structures of the neighbouring calices. The costæ are not so unequal as the septa, are faintly dentate, but slightly exsert, and are very distinct. The endotheca is sparely developed, and the exotheca exists. Diameter of calices $\frac{4}{10}$ inch.

Locality. St. Croix, Trinidad.

BRACHYPHYLLIA IRREGULARIS, spec. nov.   Plate II. fig. 5.

The corallum is short, and has a very irregular upper surface, and an encrusting base. The corallites are very irregular in their shape and dimensions. The calices are crowded, deformed, and irregular. The calicular fossa is deep. The columella is very small. The costæ are continuous, and alternately very large and very small. The septa are irregularly developed, are alternately large and small, and never exceed three cycles in six systems. There is much exotheca. The largest calices are rather more than $\frac{1}{12}$ inch in diameter.

Locality. St. Croix, Trinidad.

ASTRÆA PARIANA, spec. nov.*

The corallum is massive and rather tall, and its upper surface is flat. The corallites are slender, tall, crowded, and equal. The calices are small, and the fossa is rather deep. The columella presents one rounded process. The septa are in six systems, and there are three cycles; they are alternately large and small, and the smallest usually unite to the large septa; they are faintly dentate. The laminæ present on their sides sets of granules in horizontal but wavy lines. The endotheca is rare. The diameter of the calices is $\frac{1}{12}$ inch.

Locality. St. Croix, Trinidad.

ISASTRÆA CONFUSA, spec. nov.   Plate II. fig. 6.

The corallum is short, and covers much space. The corallites are very irregular in size, and the calices also. The fossa is moderately deep, and presents a false columella. The septa are thick, and unite laterally in sets of three, four, or six. The free margin is faintly dentate. The largest calices have four cycles of septa in six systems; but usually only three cycles are found in smaller calices. The diameter of the calices is from $\frac{1}{10}$ to $\frac{4}{10}$ inch.

Locality. St. Croix, Trinidad.

STYLOPHORA MINUTA, spec. nov.*

The corallum is encrusting and very small and thin. The calices are circular in outline, and project like small cylinders above the cœnenchyma, which separates them. The costæ are not in existence, but the cylindrical wall is plain. The septa are six in number, and are stout. The columella is large and styloid. The cœnenchyma is lax and plain. There are two calices and the intermediate cœnenchyma in $\frac{1}{10}$ inch.

Locality. St. Croix, Trinidad.

This species is closely allied to *S. raristella,* Defrance, sp., of the Faluns.

5. *Remarks on the Species.*—An analysis of the eighteen species found in the Trinitatian Miocene deposit at St. Croix, gives the following results:—

1. Species common to the West-Indian and European deposits ... 2
2. Species common to the St. Croix deposit and other West-Indian Miocene deposits 10
3. Recent species of the West-Indian Coral-fauna ...... 6 ⎫
4. Recent species of the Pacific Coral-fauna .... 1 ⎬ 7
   ⎭
5. Species peculiar to the Trinidad Miocene 6

The genus *Heliastræa* is very large, and therefore its species are by no means to be readily differentiated. Nevertheless the five species of the Trinitatian deposit are well-marked forms, the only close alliance being between *H. cylindrica* and *H. cavernosa. H. cylindrica* is the oldest species, and may have become modified to

* The specimens on which these species were founded decayed before they could be drawn, on account of their fragile and chalky nature.

meet external conditions, and may have resolved itself into *H. cavernosa*.

The assemblage of *Heliastræœ* connects the Trinidad deposit with the Nivajé shale of San Domingo and the Marl of Antigua, in a palæontological sense, and indicates a reef in some form or other.

Brachyphyllia, Reuss, is a genus whose species are for the most part of Gosau-chalk age; but there is one published species from the Miocene of Turin, and I have MS. notes of another form from Bassano. The species now described are well marked, and must suggest what has already been noticed* as regards the Coral-fauna of San Domingo, Jamaica, and Antigua—the relation between the Coral-fauna of the Hippurite-age and that of the Antillian Miocene.

Isastrœa confusa† is the third species of *Isastrœa* of the West-Indian Miocene, and is as aberrant as regards its septal arrangement as the Triassic and Liassic species; but this variation from the artificial type is to be expected in the oldest and youngest species of every large genus. The variability of species, and their aberrant forms in genera about to become extinct (that is to say, extinguished in the perceptions of the zoologist), is very marked in the Madreporaria, as it is in Echinodermata, Trilobita, and Pachydermata.

Stylophora raristella, Defrance, sp., is an abundant fossil; and very beautiful examples of the papillate cœnenchyma between the calices are very common. There is no cœnenchyma in the young corallum, but it appears with growth. The *S. minuta* is closely allied to the *S. raristella*, which is a characteristic Falunian coral.

Porites astroides, Lamarck. This is a species whose individuals are very large, and doubtless formed large portions of old reefs, as they do still in the present Caribbean sea.

Taken as a whole, the eighteen species, which are all compound, indicate vigorous coral-growth and the conditions most favourable for the existence of a reef—that is to say, pure sea-water, the absence of fresh water, a deep sea close at hand, and neighbouring high land in an area of oscillation.

These external conditions are not now in existence; and Trinidad, the southernmost of the West-Indian Islands, is too close to the delta of the Orinoco and the estuaries of the Gulf of Paria for the growth of the species of the West-Indian Coral-fauna. The Orinoco effectually stops the passage of the West-Indian species to the south. Formerly, when the great plains through which the Orinoco passes were a Miocene sea-bottom, there may have been an open sea, as large as the Caribbean, to the west and south, and the coral-reefs would have been supported by the outliers of the mica-slate ranges of Colombia.

6. *The Mineralization of the Specimens.*—The mineralization of the St. Croix specimens is somewhat peculiar. A few are imbedded

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* Duncan and Wall, *op. cit.*

† Since this written MM. Duchassaing and Michelotti (in their "Supplément au Mémoire sur les Coralliaires des Antilles, Mém. Acad. Turin, 2e série, vol. xxiii.) notice *Dimorphastrœa Guadalupensis* from the Tertiaries of Guadeloupe; the genus is of Gosau age.

in pure white chalk; but the rest are surrounded and included in the usual reef-detritus, are of a light-brown colour, are usually very hard and heavy, and present much crystalline carbonate of lime. There is nothing like the condition observed in the Antiguan fossil Corals; and, as a rule, the Mollusca imbedded with the Corals are in the form of casts.

Some of the more massive specimens of the *Heliastrœœ* and *Stephanocœniœ* present a fracture which resembles that of Echinoderm remains.

7. *Remarks on San-Domingan Fossil Corals.*—A careful examination of the collections in the Society's Foreign Museum and in the British Museum enables me to add some species to the Coral-fauna of the Nivajé shale, as well as to correct some errors in my former communication.

Better specimens of *Brachycyathus Henekeni*, nobis, and an examination of the Cretaceous species of Europe prove that the small Corals described under this genus are *Paracyathi*.

PARACYATHUS HENEKENI, Duncan, 1867.
Brachycyathus Henekeni, Duncan, 1863.

(See the specific diagnosis, Proc. Geol. Soc. May 6, 1863, p. 426.)
The pali are before the primary and secondary septa, and are largest before the tertiary when the system is complete. The pali are entire, small, and papillose. The columella is formed with the ends of the septa, and is small.

Several specimens of *Trochocyathus abnormalis*, nobis, indicate the necessity of removing the species from the genus *Trochocyathus*, and of establishing a new genus for them under the name of *Asterosmilia*.

The occurrence of pali and endotheca in three species has determined the diagnosis of this new genus, which links together the great collection of genera of simple Corals with and without endotheca, viz. the *Caryophyllinœ* and the *Astrœidœ*.

The descriptions of the new genus and species are given in Phil. Trans. Royal Soc. 1867.

ASTEROSMILIA ANOMALA, Duncan, 1867.
Trochocyathus abnormalis, Duncan, 1863.

ASTEROSMILIA CORNUTA, Duncan, 1867.

ASTEROSMILIA EXARATA, Duncan, 1867.

MANICINA AREOLATA, Linnæus, sp.

This species is common in the Caribbean sea; and a fossil specimen was found in the Nivajé shale.

FLABELLUM EXARATUM, nobis (Proc. Geol. Soc. Nov. 9, 1864).

A small specimen has been found in the Nivajé shale, the type having been discovered at Vere, in Jamaica. The species is also found in Cumana*.

* J. L. Guppy, *op. cit.*

PLACOTROCHUS LONSDALEI, nobis (Quart. Journ. Geol. Soc. vol. xix. p. 428, plate xv. figs. 2*a* and 2*b*).

The artist has omitted the columella.

It is remarkable that two species of *Placotrochus* should be found fossil in the South Australian Tertiary* deposits ; but the genus is extinct in the Caribbean area.

POCILLOPORA CRASSORAMOSA, nobis.

Reuss has lately described a *Pocillopora* (*P. Jenkinsi*) from Java, and notices its resemblance to the San-Domingan species. There is also a species in the Antiguan Tertiaries.

ANTILLIA, genus nobis (Quart. Journ. Geol. Soc. vol. xx. p. 28).

This genus, which embraces *Montlivaltiœ* with columellæ, has at least six well-marked species in the Miocene. The smallest are discoid, the rest being more or less turbinate.

M. de Fromentel does not interest himself in Tertiary Corals ; otherwise that excellent observer and able palæontologist would have been spared the necessity of introducing his genus *Cyathophyllia* in 1865. See Pal. Franç. Terrain Jurassique, p. 86.

CARYOPHYLLIA AFFINIS, nobis, 1863.

It is proposed to adopt the terminology of MM. Milne-Edwards and Jules Haime, and to name this species *Lithophyllia affinis*, Duncan, 1867.

The species formerly included in the genus *Astrœa*, such as *A. endothecata, A. cylindrica*, &c., will be named *Heliastrœa endothecata*, Duncan, *Heliastrœa cylindrica*, Duncan. *Astrœa brevis* will become *Heliastrœa brevis*, Duncan.

The genus *Siderastrœa* is replaced by *Astrœa*, so that *Siderastrœa grandis*, nobis, will become *Astrœa grandis*, Dunc. *Siderastrœa crenulata*, Blainville, will be termed *Astrœa crenalata*, Blainville, sp.

8. *Description of some new Species from Jamaica.*—The Society's Journals for 1863 and 1864 contain the descriptions of the species of Corals from Jamaica. The following additions are requisite :—

In the Eocene dark shales *Paracyathus crassus*, Ed. & Haime, is found. Its European locality is Bracklesham.

COLUMNASTRÆA EYREI, sp. nov. Plate I. figs. 1*a*, 1*b*.

The corallum is subramose, and the calices are wide apart and oblique. The costæ cover the cœnenchymal surface, are equal, are separated by deep grooves, and are usually straight and long. The calicular margins are ridged by the costæ. The septa are smaller than the costæ. The septa are deeply situate, are delicate, the laminæ being larger at the wall and near the columella than midway ; and the primary septa have small pali. There are three cycles, the last being incomplete in one or more systems. The secondary septa nearly equal the primary when the cycle is complete. The

* Ann. & Mag. Nat. Hist. ser. 3, vol. iv.

tertiary septa are very small. None of the septa are exsert. The columella is essential, stoloniform, large and projecting. Diameter of calices $\frac{1}{20}$ inch.

Locality. Eocene Shales, Jamaica.

PLACOTROCHUS SAWKINSI, spec. nov.   Plate II. fig. 2 *a*, 2 *b*.

The corallum is short, turbinate, adherent, and compressed. The epitheca is delicate, and permits the costæ to be seen near the calice. The costæ are distinct, rather unequal, and are faintly dentate. The calice is deep, and the margin is blunt. The septa are wide apart, the primary are large, slightly exsert, and have a straight inner edge.

The septal arrangement is very irregular. Thus in the

1st	system there are	8	septa, or 4 cycles				
2nd	,,	,,	6	,,	,,	incomplete.	
3rd	,,	,,	6	,,	,,	,,	
4th	,,	,,	6	,,	,,	,,	
5th	,,	,,	9	,,	,,	and part of 5th cycle	
6th	,,	,,	14	,,	,,	,,	,,

49 septa.

The higher orders of septa are very small; but their costæ are larger. The laminæ are ornamented with granules. The columella is small, central, slightly projecting, and lamellar; about 18 septal ends reach it, and become more or less adherent.

Height of the coral $\frac{1}{2}$ inch.   Length of the calice $\frac{1}{2}$ inch.

Loc. Bowden, Jamaica.

Siderastræa grandis, Duncan, becomes under the latest nomenclature *Astræa grandis,* Duncan.

9. *Remarks on the Antiguan Fossil Corals, and Descriptions of new species.*—The genus *Astræa* gives way to that of *Heliastræa,* and the genus *Siderastræa* becomes *Astræa.* Hence all the Astræans with thick septa become classified under *Heliastræa crassolamellata,* Duncan.

One of the varieties of this species, var. *pulchella,* nobis, is in Sir Charles Lyell's collection of Miocene fossils from Madeira, in the British Museum. There is, moreover, a *Heliastræa* in the collection of recent corals in the British Museum, with thick septa at the calicular margin, but it has a low septal number; nevertheless it renders the existence in the present Coral-fauna of some of these large Miocene *Heliastrææ* very probable.

In a former communication, the alliance of *Heliastræa Rochettina,* Mich., sp., with the species *crassolamellata* was omitted to be noticed. Michelin's delineation of the *H. Rochettina* is perfectly incomprehensible. The species has not four complete cycles, but is larger as regards its corallites than *H. Guettardi*; there is no other distinction, however, between these species. The costal structures of *H. Guettardi* distinguish it from *H. crassolamellata,* nobis; and the

same may be said concerning *H. Rochettina,* if it can stand as a separate species.

The species *Astræa cellulosa,* Duncan, *A. Antiguensis,* Duncan, *A. endothecata,* Duncan, *A. megalaxona,* Duncan, *A. tenuis,* Duncan, *A. Barbadensis,* Duncan, *A. costata,* Duncan, *A. radiata,* Lamarck, are now to be referred to the genus *Heliastræa.*

Alveopora microscopica, Duncan, is probably *Porites collegniana,* Mich.

Mæandrina filograna, Esper, sp., is found in the Antiguan Tertiary deposits.

HELIASTRÆA INSIGNIS, spec. nov.   Pl. I. fig. 4.

The corallum is large, and the corallites also; they are wide apart, are circular in transverse outline, and are very equal in size. The wall is stout as regards the septa and costæ, but thin in comparison with the diameter of the corallites. The septa are delicate, wide apart, long, slightly thicker at the wall than elsewhere, straight, and the primary septa are hardly any broader than the tertiary. There are three cycles of septa in the six systems, and rarely a septum of the fourth cycle is noticed in half of a system. The primary and secondary septa are of equal length, and the tertiary extend far in towards the columella. The columella is small. The costæ are long, slender, often bent, almost equal, and of about the same thickness as the septa; occasionally a rudimentary costa is seen, and is not represented by a septum. The exotheca is inclined and abundant. The endotheca is very abundant and inclined.

Diameter of corallites (costæ not included) $\frac{4}{10}$ inch.

Loc. Antiguan Tertiary deposits.

The large size of the corallites, the low septal number, the long septa and costæ, with the small columella and highly developed endotheca, distinguish this species.

STEPHANOCŒNIA REUSSI, spec. nov.   Pl. II. fig. 1.

The corallum is gibbous and massive; the corallites vary somewhat in size, but are polygonal, and are separated by consolidated walls, upon which the septo-costal ends are seen. The septa are distinct and distant; there are ten large and ten small. The ten largest septa either reach the columella, or are attached to large pali; ordinarily five or six of the large septa have pali. The pali are long and are broader than the septa; sometimes two of the smaller septa unite to a larger septum. Columella distinct and large. Young corallites have evidently six systems; but the third cycle is incomplete in all the larger corallites.

Diameter of corallites $\frac{3}{10}$ inch.

Loc. Antigua, and probably from the Marl. (Coll. Brit. Mus.)

LAMELLASTRÆA, gen. nov.

The corallum is compound; the corallites are united by their walls, and are more or less polygonal in transverse outline; the columella is essential and lamellar; the septa are alternately large

and small; and the reproduction is principally by fissiparity through the solid columella, and occasionally by marginal gemmation.

LAMELLASTRÆA SMYTHI, spec. nov.   Pl. I. figs. 2 a, 2 b.

The corallum is large and massive. The corallites vary in size, from their undergoing fissiparous division. The walls are solid and delicate. The septa are short, alternately large and very small, although a small septum often separates two smaller. The larger septa are broadest at the wall, and have a paliform tooth near the columella, and they reach further inwards than the smaller septa. The smaller septa are linear. The columella is stout, more or less lamellar, and a portion of it remains as a large septum after fissiparity. The number of large septa varies, but in small calices twelve may be counted. The endotheca is scanty.

Diameter of longest corallites undergoing fissiparity about $\frac{1}{5}$ inch; diameter of the smallest corallites $\frac{1}{10}$ inch.

Loc. Antigua, probably from the Marl (Coll. Brit. Mus.).

This genus is readily distinguished by the lamellar columella, the want of pali, and the fissiparous division. It must be classified amongst the *Faviaceæ*, and placed between the genera *Favia* and *Goniastræa*.

FAVOIDEA JUNGHUHNI, Reuss.

A specimen of the genus *Favoidea* of Reuss (Ueber fossile Korallen von der Insel Java, p. 168) presents corallites slightly larger than the type, and the septa appear slightly larger at the wall; but there is no specific difference between the type and the specimen which I found in the collection of West-Indian fossil corals in the British Museum, and whose mineralization would lead me to believe was Antiguan. The type is from the Miocene (?) of Java, whose corals have been so ably described by Reuss.

STYLOCŒNIA LOBATO-ROTUNDATA, Ed. & Haime.

This coral is very common in the Chert of Antigua. The general affinities of the species are described by me in the Geological Magazine, No. 3. It is a common Maltese coral.

ASTRÆA GRANDIS, Duncan.

A specimen of this coral, in the form of a polished section, is in the British Museum. The weathered edges present a most extraordinary appearance, and the coral there has every appearance of a *Thamnastræa*; but the continuity of the septa, and their curved nature, can be readily understood by examining the polished surfaces and by comparing them with the weathered surfaces of a Jamaican *Astræa grandis*.

DIPLOCŒNIA, gen. nov.

The corallum is massive. The corallites are polygonal and tall, united by a well-developed common wall, and present an external cœnenchymal space, an internal wall, whence arose the septa, a lamellar columella, and oblique dissepiments between the common

and internal walls. Reproduction by gemmation in the cœnenchymal space.

DIPLOCŒNIA MONITOR, spec. nov. Pl. I. figs. 3 *a*–3 *c*.

The corallites are crowded, and either hexagonal or pentagonal, and they are rarely four-sided. The inner wall is more or less circular, and the cœnenchymal space varies in size and in the amount of endotheca. The external wall is stout, wavy, imperforate, and slightly higher than the internal. The septa arise from the inner wall, and very rarely from the outer, or from the cœnenchymal space. The laminæ are linear, straight, wide apart, and do not all project to the columella, but one septum often does. Minute septa appear here and there between the others, which are subequal. The septal number is variable. In a small corallite there are 15 large septa and 3 small; in a larger, 13 large and 9 rudimentary septa; in other corallites 19 large and 5 small septa, 14 and 4, and 14 and 10 septa.

There are no costæ. The columella is lamellar and flat, but very distinct, and is often joined to one or more septa.

The endotheca between the walls is inclined and vesicular, and rather abundant, and that within the internal wall and between the septa is very sparely developed.

Diameter of largest corallites $\frac{5}{20}$ inch, the cœnenchymal space being about $\frac{1}{20}$ inch wide.

The mineralization is siliceous; and the specimen is in the British Museum, among the Antiguan corals.

This is a very remarkable genus; for it is, as it were, a *Lithostrotion* of the Palæozoic Coral-fauna without tabulæ. There is nothing like it known; and the lingering of the old type in association with vesicular endotheca and an irregular septal arrangement which is certainly not hexameral is very interesting and suggestive.

POCILLOPORA TENUIS, spec. nov. Pl. I. figs. 5 *a*–5 *c*.

The corallum is large; but the amount of intercorallite cœnenchyma is small everywhere, whilst it barely exists in some parts. The tabulæ are very delicate, rather and unequally close, and are often marked with a projection—the columella. The intertabular spaces do not fill up with coral tissue. The septa are small, very distinct, and are usually twelve in number; but in some calices there are a few rudimentary septa.

The corallites are usually crowded, and six occupy about $\frac{1}{2}$ inch.

Loc. Antigua (Coll. Brit. Mus.).

The delicate tabulæ and the patency of the intertabular spaces distinguish this species. It is interesting to observe in the same specimen portions without cœnenchyma and portions with it, especially as these two conditions are considered generic in Palæozoic corals ! *Pocillopora crassoramosa*, nobis, has much cœnenchyma; and so has *P. Jenkinsi*, Reuss, its nearest ally, from Java.

10. *List of the New Species of West-Indian Fossil Corals.*

TRINIDAD.

1. Heliastræa cavernosa, *Esper*, sp., recent, Caribbean Sea.
2. —— altissima, sp. nov.   5. Astræa Pariana, sp. nov.
3. Brachyphyllia Eckeli, sp. nov.   6. Isastræa confusa, sp. nov.
4. —— irregularis, sp, nov.   7. Stylophora minuta, sp. nov.
8. Stylophora mirabilis, *Duch. & Mich.*, recent, Caribbean Sea.
9 —— raristella, *Def.*, sp., Miocene of Dax.
10. Porites astroides, *Lamarck*, recent, Caribbean Sea.

SAN DOMINGO.

11. Asterosmilia cornuta, sp. nov.   12. Asterosmilia exarata, sp. nov.
13. Manicina areolata, *Linnæus*, sp., recent, Caribbean Sea.

JAMAICA.

14. Columnastræa Eyrei, sp. nov. (Eocene).
15. Placotrochus Sawkinsi, sp. nov. (Miocene).

ANTIGUA.

16. Heliastræa insignis, sp. nov.   17. Stephanocœnia Reussi, sp. nov.
18. Lamellastræa Smythi, sp. nov. et gen. nov.
19. Favoidea Junghuhni, *Reuss*, Java, Miocene.
20. Stylocœnia lobato-rotundata, *E. & H.*, Europe, Miocene.
21. Diplocœnia monitor, sp. nov. et gen. nov.
22. Pocillopora tenuis, sp. nov.

11. *Table of the Synonyms and Localities of all the Species of the West-Indian Miocene, Eocene, and Cretaceous Coral-faunæ.*

Present Names.	Synonyms.	Localities &c.
1. Caryophyllia Guadalu-pensis, *Ed. & H.*	Cyathina Guadalu-pensis, *Ed. & H.*	Guadeloupe, Miocene.
2. Paterocyathus Guada-lupensis, *Duch.&Mich.*	....	,, ,,
3. Paracyathus Henekeni, *Dunc.*	Brachycyathus He-nekeni.	San Domingo, ,,
4. —— crassus, *Ed. & H.*	....	Jamaica, Eocene; Europe, Eocene.
5. Trochocyathus cornu-copiæ, *Ed. & H.*	....	San Domingo; Europe, Miocene.
6. —— laterospinosus, *Ed. & H.*	....	,, ,, ,,
7. —— profundus, *Dunc.*	....	,,
8. —— obesus, *Mich.*	....	Jamaica; Europe, Miocene.
9. Placocyathus Barretti, *Dunc.**	....	San Domingo; Jamaica.
10. —— variabilis, *Dunc.**	....	,,
11. —— costatus, *Dunc.*	....	
12. —— Moorei, *Dunc.*	....	Jamaica.
13. Flabellum dubium, *Dnc.*	....	San Domingo.
14. —— exaratum, *Dunc.*	....	Jamaica.
15. Placotrochus Sawkinsi, *Dunc.*	....	,,
16. —— costatus, *Dunc.*	....	,,
17. —— Lonsdalei, *Dunc.*	....	San Domingo.
18. —— alveolus, *Dunc.*	....	Jamaica.

* Species thus distinguished have varieties which have been described.

Present Names.	Synonyms.	Localities &c.
19. Ceratotrochus duode-cimcostatus, *Ed. & H.*	....	San Domingo ; Europe, Miocene.
20. Asterosmilia abnorma-lis, *Dunc.*	Trochocyathus ab-normalis, *Dunc.*	,,
21. —— cornuta, *Dunc.* ...	....	,,
22. —— exarata, *Dunc.* ...	....	,,
23. Trochosmilia Laurenti, *Duchass. et Mich.*	....	Guadeloupe, Miocene.
24. —— gracilis, *Duchass. et Mich.*	....	,,
25. Parasmilia nutans, *Du-chass. et Mich.*	....	,,
26. Thysanus corbicula, *Dunc.*	....	San Domingo.
27. —— excentricus, *Dunc.*	....	Jamaica.
28. —— elegans, *Dunc.* ...	....	,,
29. Barysmilia intermedia, *Dunc.*	....	San Domingo.
30. Dichocœnia tuberosa, *Dunc.**	....	,,
31. Lithophyllia affinis, *Dunc.*	Caryophyllia affi-nis, *Dunc.*	,,
32. Antillia ponderosa, *Ed. & H.*, sp.	Montlivaltia pon-derosa.	San Domingo ; Jamaica ; St. Thomas ; Travancore.
33. —— dentata, *Dunc.* ...	....	San Domingo.
34. —— Lonsdaleia, *Dunc.*	....	,,
35. —— bilobata†, *Dunc.* .	....	,,
36. —— Walli, *Dunc.*.......	....	Jamaica.
37. Teleiophyllia grandis, *Dunc.*	....	San Domingo.
38. —— navicula, *Dunc.*....	....	,,
39. Manicina areolata, *Linn.* sp.	....	San Domingo ; and recent, Ca-ribbean.
40. Stephanocœnia tenuis, *Dunc.*	....	Antigua.
41. —— Reussi, *Dunc.*......	....	,,
42. —— dendroidea, *Ed. & Haime.*	....	San Domingo ; and recent.
43. —— intersepta, *Esper*, sp.	....	San Domingo; Guadeloupe; Trini-dad ; recent, Caribb. and Pacific.
44. Phyllocœnia sculpta, *Ed. & H.*	....	San Domingo ; Europe.
45. —— limbata, *Dunc.* ...	....	,,
46. Astrocœnia ornata, *Ed. & H.*	....	Antigua ; Europe, Miocene.
47. ——decaphylla, *Ed. & H.*	....	Jamaica ; Europe.
48. Stylocœnia lobato-ro-tundata, *Ed. & H.* ...	....	Antigua ; Europe, Miocene.
49. —— emarciata, *Lam.*...	....	Jamaica ; Europe, Eocene.

† MM. Duchassaing and Michelotti consider this to be their *Turbinolia biloba,* and name it *Antillia Guesdesii.* After placing this form in the genus *Turbinolia* they removed it to the remote genus *Montlivaltia,* and finally they seek to find it a resting-place in the *Antilliæ.* From the description of *Mont-livaltia Guesdesii* I cannot admit that it is my *Antillia bilobata,* The same authors notice *Trochosmilia (Turbinolia) dentata,* Duchass., from the Tertiary beds of Guadeloupe. I have not found any species of the genus in any of the collections I have examined.

Present Names.	Synonyms.	Localities &c.
50. Columnastræa Eyrei, *Dunc.*	....	Jamaica, Eocene.
51. Lamellastræa Smythi, *Dunc.*	....	Antigua.
52. Favoidea Junghuhni, *Reuss.*	....	„ Java.
53. Cœloria labyrinthiformis, *Ellis,* sp.	....	„ recent, Caribbean.
54. —— dens-elephantis, *Dunc.*	....	„
55. Astroria polygonalis, *Dunc.*	....	„
56. —— affinis, *Dunc.*......	....	„
57. —— Antiguensis, *Dunc.*	....	„
58. Diploria crassolamellosa, *Ed. & H.*	....	Jamaica ; Europe, Cretaceous.
59. Mæandrina filograna†, *Esper,* sp.	....	San Domingo ; Antigua ; recent, Caribbean.
60. —— sinuosissima, *Ed. & H.*	....	„
61. Heliastræa crassolamellata, *Dunc.*＊	Astræa crassolamellata.	Antigua.
62. —— Antiguensis, *Dnc.*	—— Antiguensis .	„
63. —— endothecata, *Dnc.*＊	—— endothecata .	„ San Domingo.
64. —— tenuis, *Dunc.*......	—— tenuis	„
65. —— Barbadensis, *Dnc.*	—— Barbadensis .	„ Trinidad ; Barbadoes.
66. —— costata, *Dunc.* ...	—— costata	„
67. —— cellulosa, *Dunc.*＊	—— cellulosa......	„
68. —— megalaxona, *Dnc.*	—— megalaxona .	„
69. —— radiata, *Ellis*＊, sp.	—— radiata	„ recent.
70. —— cylindrica, *Dunc.* .	—— cylindrica ...	San Domingo ; Trinidad.
71. —— Antillarum, *Dunc.*	—— Antillarum...	Montserrat ; Antigua ; San Domingo.
72. —— brevis, *Dunc.*......	—— brevis	San Domingo. [mingo.
73. —— exsculpta, *Reuss,* sp.	....	Jamaica ; Europe, Cretaceous.
74. —— cyathiformis, *Dnc.*	....	„ „
75. —— altissima, *Dunc.*...	....	Trinidad.
76. —— insignis, *Dunc.* ...	....	„
77. —— cavernosa, *Esper,* sp.	.... ‡	Trinidad, Guadeloupe ; recent, Caribbean.
78. Cyphastræa costata, *Dunc.*	....	San Domingo ; Barbuda ; Jamaica.
79. Brachyphyllia Eckeli, *Dunc.*	....	Trinidad.
80. —— irregularis, *Dunc.*	....	„
81. Astræa crenulata, *Blainville*＊.	Siderastræa crenulata.	San Domingo ; Europe, Miocene.
82. —— grandis, *Dunc.* ...	—— grandis.	Jamaica ; Antigua.
83. —— Pariana, *Dunc.* ...	....	Trinidad.
84. Isastræa confusa, *Dunc.*	....	„

† MM. Duchassaing and Michelotti have found *Mæandrina superficialis*, Ed. & H., and *M. interrupta*, Dana, in the Pliocene deposits of Guadeloupe and I have a specimen of the first species from a raised beach in Cuba.

‡ MM. Duchassaing and Michelotti have found *H. acropora*, Ed. & H., fossil at Guadeloupe ; it is still existing as a species. They have found *Dimorphastræa Guadalupensis*, Duch. & Mich., in the tertiaries of the island of Guadeloupe.

Present Names.	Synonyms.	Localities &c.
85. Isastræa conferta, *Dunc.*	....	Antigua.
86. —— turbinata, *Dunc.*	....	,,
87. Solenastræa Ellisii, *Duch. & Mich.*	....	St. Thomas.
88. —— Verhelsti, *Ed. & H.*	....	San Domingo, Miocene; Europe, Eocene.
89. —— Turonensis, *Mich.*	....	Antigua; Europe, Miocene.
90. Plesiastræa distans, *Dunc.*	....	San Domingo.
91. —— globosa, *Dunc.*	....	,,
92. —— spongiformis, *Dnc.*	....	,,
93. —— ramea, *Dunc.**	....	,,
94. Stylophora affinis, *Dnc.**	....	,,
95. —— raristella, *Ed. & Haime.*	....	,, Trinidad; Europe, Miocene.
96. —— contorta, *Leymerie, sp.**	....	Jamaica; Europe, Eocene.
97. —— minuta, *Dunc.*	....	Trinidad.
98. —— mirabilis, *Duch. & Mich.*	....	,, recent, Caribbean.
99. —— granulata, *Dunc.*	....	Jamaica.
100. Diplocœnia monitor, *Dunc.*	....	Antigua.
101. Rhodaræa irregularis, *Dunc.*	....	,,
102. Alveopora dædalæa, *Blainv.** or *Forsk.*	....	,, recent, Pacific.
103. —— fenestrata, *Lam.*	....	,, ,,
104. Pocillopora tenuis, *Dunc.*	....	,,
105. —— crassoramosa, *Dunc.*	....	San Domingo,
106. Agaricia agaricites, *Lamarck.*	....	San Domingo; Trinidad; recent.
107. —— undata, *Lam.*	....	Trinidad; San Domingo; recent.
108. Cyathoseris Haidingeri, *Reuss.*	....	Jamaica; Europe, Cretaceous.
109. Porites Collegniana, *Mich.*	....	San Domingo; Europe, Miocene.
110. —— Reussiana, *Dunc.*	....	Jamaica, Cretaceous.
111. —— astroides, *Lamk.*	.... §	Trinidad, Guadeloupe; recent, Caribbean.

12. *Table of the Varieties of Species.*

Present Names.	Synonyms &c.	Localities &c.
Placocyathus Barretti, *Dunc.* Var. I. II.	....	San Domingo.
Placocyathus variabilis, *Dunc.* Var. I. II. III. IV.	....	San Domingo.

§ MM. Duchassaing and Michelotti have given this species a new gene name, *Neoporites.*

Present Names.	Synonyms &c.	Localities &c.
Dichocœnia tuberosa, *Dunc.* . Var. I.	....	San Domingo.
Heliastræa crassolamellata, *Dunc.*	Astræa crassolamel-lata.	Antigua.
Var. magnetica. pulchella.............. nobilis. minor. Nugenti. magnifica.	....	Madeira.
Heliastræa endothecata, *Dunc.* Var. I. II. III.	Astræa endothecata	Antigua; San Domingo; Trinidad.
Heliastræa cellulosa, *Dunc.* . Var. curvata.	Astræa cellulosa	Antigua.
Heliastræa radiata, *Lamk.* ... Var. intermedia.	Astræa radiata	Antigua; Trinidad.
Heliastræa Antillarum, *Dunc.* Var. I.	Astræa Antillarum .	Montserrat; Antigua.
Astræa crenulata, *Blainv.* ... Var. Antillarum.	Siderastræa crenulata	San Domingo; Europe.
Stylophora affinis, *Dunc.*...... Var. minor. Var. II.	....	San Domingo.
Stephanocœnia intersepta, *Ed. & H.* Var. I.	....	San Domingo; Trinidad.
Stylophora contorta, *Leymerie.* Var. I.	....	Jamaica.
Alveopora Dædalæa, *Blainv.* Var. regularis. minor.	....	Antigua.
Plesiastræa ramea, *Dunc.*...... Var. I.	....	San Domingo.
Agaricia undata, *Lamk.* ...... Var. I.	....	Trinidad; San Domingo.

13. *The Nature and Alliances of the Coral-faunæ.*—The total number of species in the West-Indian fossil Coral-faunæ are the following (Pliocene species are not included, see note †, p. 24) :—

	Species.	Varieties.		Forms.
In Cretaceous strata	5	0	=	5
In Eocene strata	4	1	=	5
In Miocene strata	102	26	=	128
	111	27		138

Of the Miocene species eleven are still existing, viz. :— .

Manicina areolata, *Linn.*, sp. .... Caribbean Sea.
Stephanocœnia intersepta, *Esper*, sp. .... Caribbean and Pacific seas.
Mæandrina filograna, *Esper*, sp. .... Indian seas, American ?
—— sinuosissima, *Ed. & Haime* .... American seas.
aⁿHeliastræa radiata, *Ellis*, sp. .... Caribbean Sea.
Guₑ— cavernosa, *Esper*, sp. ...., Caribbean Sea.

Alveopora Dædalæa, *Forskål,* sp. .... Red Sea and Pacific Ocean.
—— fenestrata, *Lamk.,* sp. .... Pacific Ocean.
Agaricia agaracites, *Lamk.,* sp. .... Caribbean Sea.
—— undata, *Lamk.,* sp. .... Caribbean Sea and Pacific
                                                      Ocean.
Porites astroides, *Lamk.* .... Caribbean Sea.

Six species are thus undoubtedly represented in the present Caribbean Coral-fauna; two species are not now found in the Caribbean Sea, but exist in the Red Sea and Pacific Ocean; and three species are found both in the Caribbean and the Pacific Coral-faunæ.

	Species.
Caribbean and recent	6
Pacific and Red Sea	2
Caribbean and Pacific...	3
	——
	11

There are several species common to European and other strata and the West-Indian Miocene.

1. Trochocyathus cornucopiæ, *Mich.,* sp. .... Miocene of Tortona, and
                                                     Vienna basin.
2. —— laterospinosus, *Ed. & H.* .... Miocene of Turin.
3. —— obesus, *Michelotti,* sp. .... Miocene of Tortona.
4. Ceratotrochus duodecimcostatus, *Goldf.,* sp. . Miocene of Turin and Albergo.
5. Astrocœnia ornata, *Mich.,* sp. .... Miocene of Turin, &c.
6. Phyllocœnia sculpta, *Mich.,* sp.................. Lower Chalk of Martigues.
7. Astrocœnia decaphylla, *Mich.,* sp.............. Lower Chalk of Gosau.
8. Stylocœnia lobato-rotundata, *Ed. & H.*......... Miocene of Malta and Turin.
9. Favoidea Junghuhni, *Reuss* .... Miocene of Java.
10. Astræa crenulata, *Goldf.,* sp..................... Miocene of Bohemia and
                                                     Plaisance.
11. Stylophora raristella, *Def.,* sp .... Miocene of Dax and Turin.
12. Porites Collegniana, *Mich.*........................ Miocene of Vienna and Turin.

The species common to the European Miocene, and the recent Coral-fauna and the West-Indian Miocene being omitted, there remains a fauna which is essentially characteristic of the West-Indian Miocene. By comparing the genera of this fauna with those of other faunæ, some interesting results are obtained.

Alliances of the Characteristic Genera and Species.

Caryophyllia Guadalupensis, *Ed. & H.* ... to Caryophylliæ of Mediterranean
                                              and of Turin Miocene.
Paracyathus Henekeni, *Dunc.* .... to Parcyathus Turonensis, *Ed. & H.,*
                                              Turin Miocene.
Placocyathus, genus, *Dunc.* .... to Placocyathus apertus, *Ed. & H.,*
                                              Pacific.
Flabellum, genus, *Less.* .... to recent Pacific and Miocene forms.
Placotrochus, genus, *Ed. & H.* .... to Chinese and Pacific recent species;
                                              Australian Tertiary species.
Antillia, genus, *Dunc.* .... to Antilliæ of Sindh and Australian
                                              Tertiaries.
Cœloria, genus, *Ed. & H.* .... to the genus as developed in the
                                              Pacific and Red Sea.
Astroria, genus, *Ed. & H.* .... to Red Sea species.

Heliastræa, genus, *Ed. & H.* .... to Miocene species, West-Indian recent, Pacific recent.

Brachyphyllia, genus, *Ed. & H.* .... to species of the Italian Miocene.

Plesiastræa, genus, *Ed. & H.* .... to Australian, Indian Ocean, and Caribbean recent species and European Miocene species.

Rhodaræa, genus, *Ed. & H.* .... to Australian, Chinese, and Indian Miocene species.

Pocillopora, genus, *Lamk.* .... to species of Java Miocene, and recent species from Pacific, Australia, Ceylon, and Red Sea.

Alveopora, genus, *Lamk.* .... to ditto, ditto.

It is evident from this Table that the alliances of the bulk of the species of the West-Indian Miocene deposits are closest with the recent Coral-fauna of the Pacific, Indian Ocean, Red Sea, and Australian seas, and with that of the Miocene of the Australian, Javan, Sindhian, and European Tertiaries. It is very remarkable that, of the fourteen genera just mentioned, seven should not be represented in the present West-Indian Coral-fauna, but that they are in the Eastern Seas, S. Pacific, Indian and Red Sea faunæ. In the Javan Tertiaries, whose Corals have been so ably described by Reuss, the genera *Pocillopora, Alveopora,* and *Favoidea* are prominent members; but the general appearance of the Coral-fauna does not convey the idea that the Javan and Caribbean Miocene deposits had a very close homotaxis. There is that singular relation to Eocene forms in the Javan Miocene (which Mr. Jenkins and myself have alluded to, Quart. Journ. Geol. Soc. 1864, vol. xx. p. 45) very strongly developed in the case of the *Madreporaria.* This is not observed in the West-Indian Miocene Coral-fauna.

The Corals of the Australian Tertiaries are becoming better known, and there are species and genera of them identical with European Miocene deposits; but the majority of the forms are peculiar. Nevertheless the genera *Placotrochus, Flabellum, Antillia,* and *Trochocyathus,* which are represented in the Caribbean Miocene, and which do not exist in the recent West-Indian Coral-fauna, are prominent members of some of the Australian Tertiary Coral-faunæ.

Up to the present time no affinity can be traced between the Australian and the Javan Coral-faunæ.

14. *Conclusion.*—The only Cretaceous Corals of the West-Indian Islands which have been described are from Jamaica; and they indicate the former existence of a Coral-fauna singularly like that of the Lower Chalk of Gosau and of Martigues, accompanying a fauna of Rudistes. There is an identity of species between the West-Indian Cretaceous Corals and the European; and there can be no doubt about these widely spread Lower Cretaceous strata representing the Coral-areas of the period.

Jamaica has also yielded the species of an Eocene Coral-fauna; but they prove that the shales beneath the Miocene-beds had a Coral-fauna like the London Clay, the Bracklesham beds, and the Paris basin. The Coral-assemblage which is characteristic of the Num-

mulitic strata of Sindh is not represented in the West Indies ; and the widely spread species of the London Clay and Bracklesham age prove that there were two Coral-faunæ in the Eocene period, just as there are two great divisions of Coral-life at the present day.

The Miocene Coral-fauna of the West-Indian Islands had a greater number of genera and species than is possessed by the existing Coral-fauna of the Caribbean Sea.

Moreover the variety of solitary or simple Corals, whose existing analogues live in deep but not in profoundly deep water, was as marked a peculiarity of the Midtertiary fauna as the comparative absence of such species is of the existing fauna.   In fact, the Miocene Coral-fauna of the Antilles bears a very creditable comparison with that which dwells in the oceans and seas between Eastern Africa and the Western coast of America.   There is every kind of sea-bottom in the great Indo-Pacific Coral-sea, besides great variation in the depth of the sea and in the external conditions affecting Madreporarian life.   Consequently there are solitary Corals there in abundance, and the commonest solitary species of the West-Indian Miocene have more or less close allies in some area or other of the great ocean.

It appears that, whilst Jamaica, San Domingo, and Guadeloupe present solitary species mixed with those indicating shallow water and a reef, Antigua and Trinidad offer for consideration only reef-species.   There existed therefore, in all probability, a barrier-reef in moderately deep water in the northern part of the former Coral-sea, and atolls and abyssal depths near the Atlantic.

It is worthy of remark that the commonest genera of the reefs now existing around and about many of the West-Indian Islands are *Porites*, *Millepora*, and *Madrepora*.   Now, there is hardly a trace of these in the Miocene deposits, and they are represented by the genera *Pocillopora* and *Alveopora*, which are characteristic of Pacific reefs, and which have no species now living in the Caribbean Sea.

The identity of several Antiguan, Trinitatian, Jamaican, and San-Domingan species with those long considered characteristic of many European Miocene deposits was thought to bear strongly upon the question of a Miocene archipelago connecting the Pacific with the West-Indian and the Mediterranean seas, or rather the areas about them which were coralliferous.   The affinity of the Miocene Coral-species of the West Indies with those of the Miocene of Travancore and Java, the identity of some species of the Mollusca, Echinodermata, and Foraminifera in the Antillian deposits and in the Faluns, the Maltese limestones, and the Miocene beds of Asia Minor, and the recent discovery of a dominant Antiguan Miocene Heliastræan in the Miocene of Madeira tend to the belief in the former existence of a belt of scattered islands where there is now no trace of land, and that the Atlantic and the great sea-desert of the Eastern Pacific were Miocene Coral-tracts.   This theory was considered in my earliest communication on the fossil Corals of the West-Indian Islands ; and a further examination of its merits may perhaps impress geologists of its truth ; for there are evidences that this connexion

between southern Europe and the Antilles, and probably with the Pacific, was kept up during the deposit of the Crag, and even into the Glacial period. Few facts in the natural history of late Tertiary times are more interesting than the dispersion of the Crag Mollusca; and the discovery of numerous species of them living on the west, Pacific coast of North America, and of some in the West Indies, is as important as that of the offshoots of the Mediterranean algæ, which do not exist to the north of Florida, but which flourish in the neighbourhood of the Coral-tracts of the northern part of the Caribbean Sea, constituting one-third part of the marine flora. The recent Coral-fauna of the Caribbean Sea has several genera with a very decided modern Mediterranean facies; it has none of the commonest genera of the Pacific Coral-fauna; and it has been already observed that the distinction between the Miocene Coral-forms of the West Indies and those now existing there is very great.

It is most probable therefore that with the gradual elevation of the vast tracts of reef and of sea-bottom in the Caribbean Sea, and on all sides of it except the east, there must have been such alterations in the general contour of the sea-shores, such modifications of land-drainage, and so many adverse external conditions, that the species of solitary Corals especially must have suffered rapid extinction, and the reef-species must have dwindled down and given way to the hardy *Porites* and *Madrepora* so characteristic of the present reefs of the Antilles.

The whole of the *Madreporaria* are incapable of any other kind of migration than by the dispersion of ova by currents in the sea. The ova are ciliated, and readily attach themselves to substances; but they require for their growth and development the same external conditions as the mature forms. The external conditions have been so fully described by Darwin, Dana, and others, that it is only necessary to observe that the conditions are so peculiar that the discovery of unrolled *Madreporaria* in fossiliferous deposits, at once satisfies the geologist that the peculiar physical state of things was there present. Very slight alterations in the physical geography of a Coral-tract interfere with Coral-growth, and destroy it if they are persistent. The value of the evidence afforded by fossil Corals is therefore great; and in estimating it the fact must be considered that several genera of the Gasteropoda, many species of perforating Mollusca, and several genera of fishes depend upon Coral-life for their existence.

The Orinoco drains a vast Tertiary region, and shuts in the Coral-life of the Caribbean on the south; for no corals can live near its waters; the Florida reefs consist of few species, and the corals of the Bermudas are the most northerly *Madreporaria*; and there are no reefs in the Atlantic. It therefore happens that the species of the present Caribbean Sea are singularly localized; and this separation from the influences of the Pacific Coral-tracts dates principally from the commencement of the upheaval of the Miocene deposits of the Isthmus, although it is probable that the isthmus did not become complete until during the Pliocene age. There is some reason in the conjecture that the upheaval of the whole of the Antilles was

synchronous; for the dip of the strata is constantly from the centre of the space whose circumference is indicated by the present Antilles; and if this was so, there is a probability that the areas of more or less contemporaneous subsidence were in the Eastern Pacific, and between the West Indies and Madeira.

The palæontology of the raised reefs and coralliferous strata of the Pacific Archipelago is in its infancy; and the examination of the Madreporarian remains will be of the greatest interest. It is hoped that the descriptions of the fossil Corals of the West Indies will assist these investigations, and that, following Reuss in his studies of the fossil Corals of Java, the affinity between the Miocene Coral-reefs of the Pacific and West Indies may be firmly established.

POSTSCRIPT.—Since this communication was read, I have received the Proceedings of the Essex Institute, United States, for February 21, 1866. Mr. N. S. Shaler read on that date a paper, "Notes on the Modifications of Oceanic Currents in Successive Geological Periods." He states, p. 302, "No palæontological evidence, tending to prove the former connexion of the Atlantic and Pacific Oceans in intertropical regions, has yet been published, so far as is known to the author." Whilst I regret that Mr. Carrick Moore's able palæontological proofs were unknown to Mr. Shaler, and that those I have published have not reached the Essex Institute, it is satisfactory to find the author of the 'Notes' writing thus about the upheaval of Central America :—"The emergence of this region could not have accomplished the disruption of the equatorial current at this point until the Tertiary period had been somewhat advanced." This is a satisfactory conclusion, and is very creditable to the perspicuity of Mr. Shaler; for, as he does not allude to the labours of Forbes and Godwin-Austen and Maury in any part of his essay, we may take for granted that he had not the benefit, as we have, of their researches.

Mr. A. E. Verrill gives some very interesting notes "On the Polyps and Corals of Panama, with descriptions of New Species," Proc. Essex Institute, p. 323, April 18, 1866. He states :—"The differences in the character of the Polyp-fauna of the Atlantic and Pacific sides of Central America are very remarkable. At Aspinwall coral-reefs occur having essentially the same features as those of Florida and the West Indies." "But at Panama none of these forms occur, nor even any of the genera of the families to which they belong, with the exception of *Porites*." "The *Millepora alcicornis*, so abundant on the Atlantic side, even at Aspinwall, is not represented at Panama; but *Pocillopora*, an almost exclusively Pacific and Indian-Ocean genus, is the most nearly allied form found at Panama." Mr. Verrill proceeds to notice the existence of the genus *Astrangia* as peculiarly characteristic of the Panama region. He adds :—"These remarkable differences between the two faunæ do not favour the theory that has been entertained by some geologists, that there has been a communication between the two oceans at this point, and that the gulf-stream flowed across the isthmus into

the Pacific within comparatively recent geological times." Mr. Verrill sums up thus :—" Therefore, had the gulf-stream ever flowed across the isthmus since the commencement of the Tertiary period, we ought to find, if not living corals identical with those at the West Indies, at least elevated remains of former reefs of similar kinds, no traces of which are yet known." I must refer Mr. Verrill to the " traces" published by Reuss as regards Java, by Mr. Carrick Moore and Mr. Guppy concerning Jamaica and Trinidad, and by myself in the " Fossil Corals of the West-Indian Islands."

Whilst this communication was passing through the press, the Society received the ' Memorie della Reale Accademia delle Scienze di Torino,' Serie Seconda, vol. xxiii. 1866. In this volume there is a most elaborate and valuable contribution by MM. P. Duchassaing de Foubressin et Jean Michelotti, in the form of a supplement to their essay on the Coralliaires des Antilles, which was noticed in the first part of the " Fossil Corals of the West-Indian Islands." This important supplementary essay appears to have been read on May 3, 1863, but was only published in 1866 ; consequently MM. Duchassaing and Michelotti had not received my essay on the Geology of Jamaica, February 1865, when they wrote ; but it was published long before their essay was printed. Several species which I have described are therefore not included in their list of fossil Corals.

It is very interesting to notice how the careful studies of these naturalists tend to enhance the views I have advocated, and to prove that the Miocene and existing Coral-fauna of the Caribbean are very different. I have introduced some of the facts collected by MM. Duchassaing and Michelotti in footnotes, and, whilst acknowledging the studious care with which they have recorded my labours, I venture to make the following remarks ; for it is evident that on some subjects there is a mutual misconception. With regard to my retaining the genus *Cyathina* instead of *Caryophylla*. Following the procedure of MM. Milne-Edwards and Jules Haime, I adopted " *Cyathina*," and, like those palæontologists, when I saw that *Caryophyllia* ought to have priority, I adopted what Messrs. MM. Duchassaing and Michelotti term " Ce procédé très-logique." In my supplement to the " British Fossil Corals," Palæontological Society, London, 1866, this fact is obvious.

In my " Geology of Jamaica," which forms part of this series of ' Essays on the West Indian Fossil Corals,' February 1865, it will be observed that I am also " très-logique ; " for I follow MM. Milne-Edwards and Jules Haime, and term *Astræa* " *Heliastræa*." The synonymy of the fossil Corals which I have given I trust will satisfy my fellow-labourers in West-Indian Geology. *Caryophyllia Berteriana*, Duchass., is a recent species at Guadeloupe ; and therefore there is a (*Cyathina*) *Caryophyllia* in the Caribbean.

I do not think that, because several *Placocyathi* have been found fossil in the West-Indian Miocene deposits, *P. apertus*, a recent form, whose habitat is unknown, should have a Caribbean habitat given to it, but the contrary.

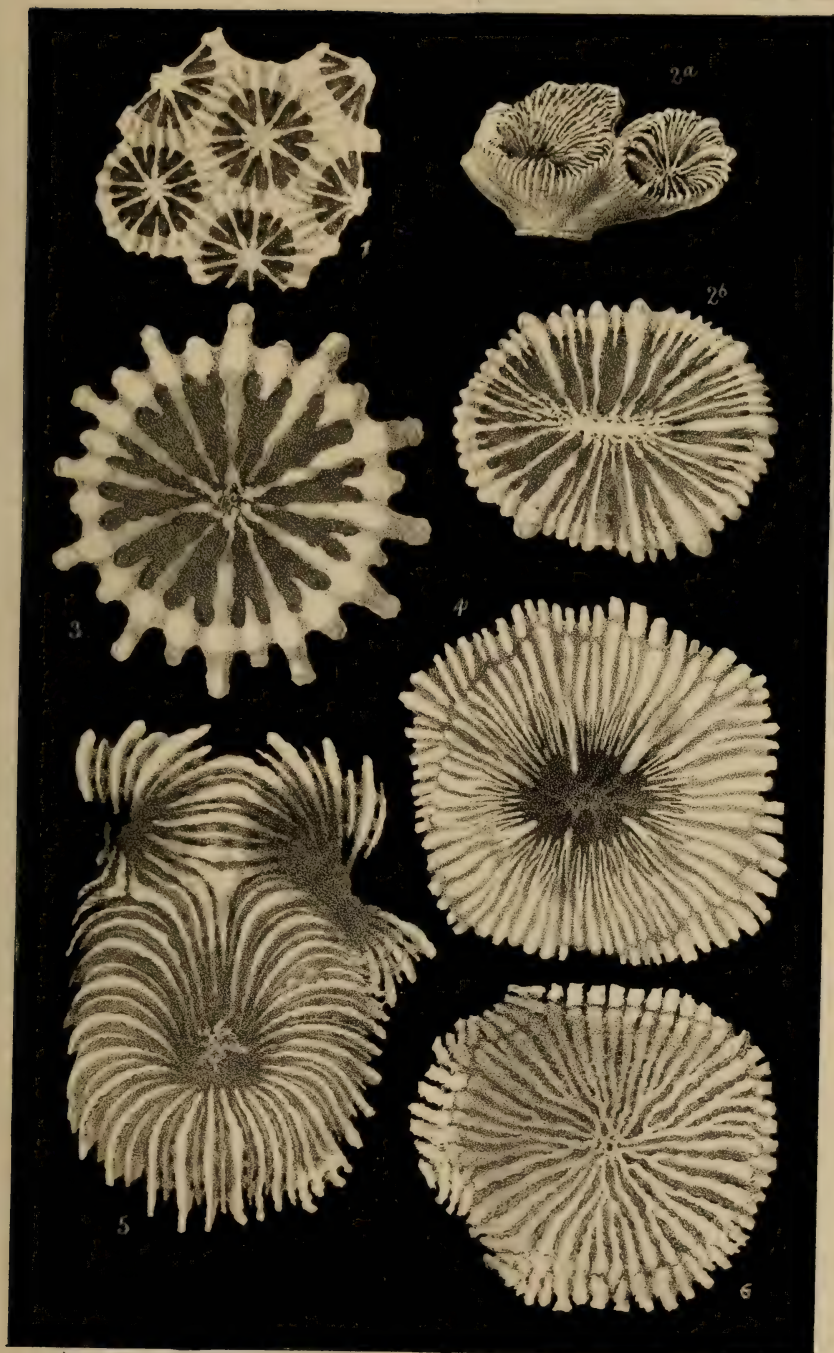MM. Duchassaing and Michelotti notice that, although they
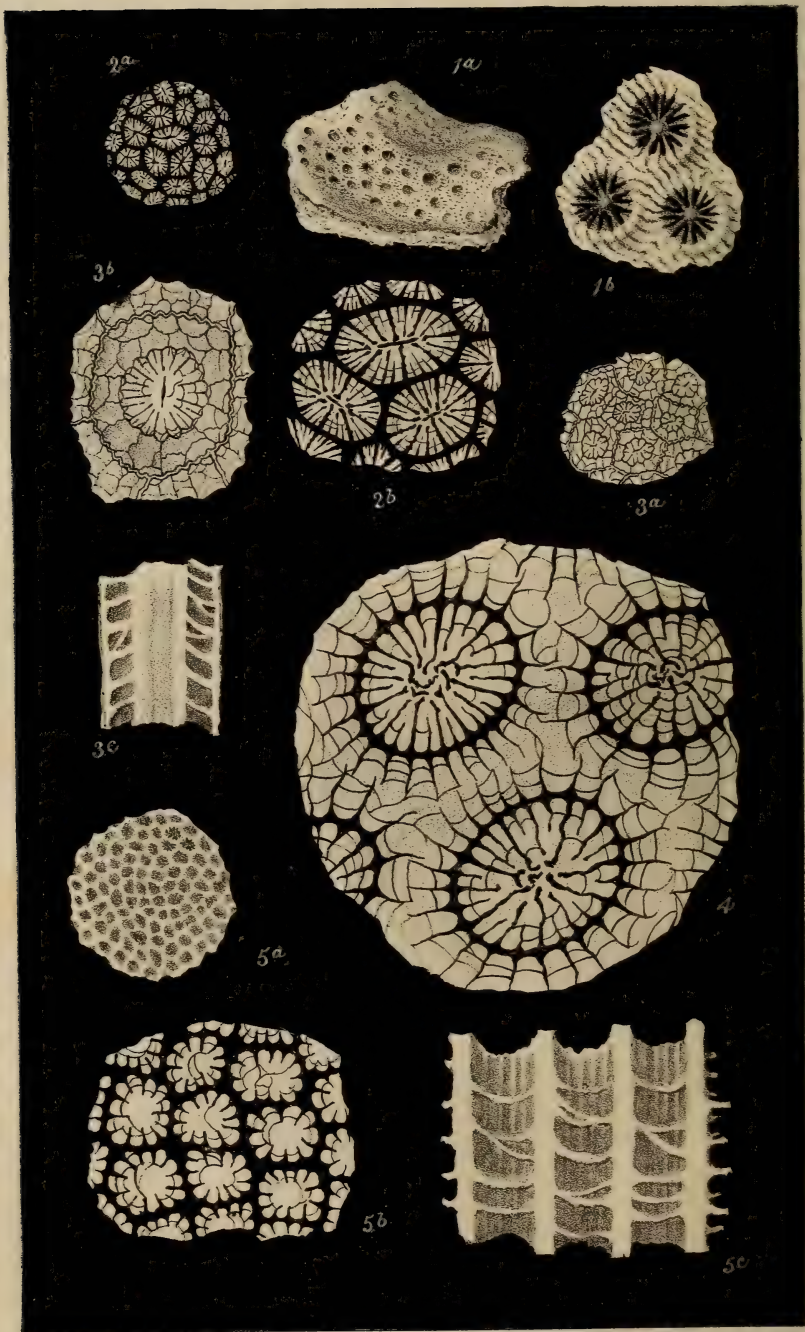
WEST INDIAN FOSSIL CORALS.

De Wilde lith.

M & N Hanhart imp

WEST INDIAN FOSSIL CORALS.

describe five species of *Desmophyllum* from the recent Caribbean
Coral-fauna, it is " pourtant singulier " that I should not mention a
single fossil species.   Now this proves to me that my able fellow-
labourers only study " d'autres ouvrages, outre ceux qu'on publie
en Angleterre" (p. 157); for, according to what I have written, it
would be " pourtant singulier " if there were fossil species of *Des-
mophyllum* in the West-Indian Miocene. Mr. A. E. Verrill will find
many species of the genus *Astrangia* noticed in the Caribbean Sea.
M. Duchassaing and Michelotti give a Silurian age to *Favosites
Dietzi*, Duch. & Mich., and *F. Sancti Thomœ*, Duch. & Mich.   I
retain my species *Lithophyllia affinis*, as it presents sufficient struc-
tural differences to prevent its being called *L. lacera*.

The *Isastrœa* I described has spines on its septa, and only the
base has been rolled or shows the effects of rolling; this is clearly
stated in the description of the species. It is impossible to confound
any species of the genus with *Plesiastrœa*, whose calices are free and
whose septa have pali.

<div align="center">EXPLANATION OF PLATES I. & II.</div>

<div align="center">PLATE I.</div>

Fig. 1. *a. Columnastrœa Eyrei*, sp. nov.   The corallum nat. size.
      b. Calices magnified.
   2. *a. Lamellastrœa Smythi*, sp. nov.   Transverse section, nat. size.
      b. Transverse section of corallites, magnified.
   3. *a. Diplocœnia monitor*, sp. nov.   Transverse section, nat. size.
      b. The same section, magnified.
      c. Longitudinal section, magnified.
   4. *Heliastrœa insignis*, sp. nov.   Transverse section of a corallite, mag-
         nified 2 diameters.
   5. *a. Pocillopora tenuis*, sp. nov.   Transverse section, nat. size.
      b. The same, magnified.
      c. Longitudinal section, magnified.

<div align="center">PLATE II.</div>

   1. *Stephanocœnia Reussi*, sp. nov.   Transverse section, magnified.
   2. *a. Placotrochus Sawkinsi*, sp. nov.   Corallum, natural size.
      b. The calice, slightly magnified.
   3. *Heliastrœa altissima*, sp. nov.   Calice, magnified.
   4. *Brachyphyllia Eckeli*, sp. nov.   Calices, magnified.
   5. —— *irregularis*, spec. nov.   Calices, magnfied.
   6. *Isastrœa confusa*, spec. nov.   Calice, magnified.

PROCEEDINGS

THE GEOLOGICAL SOCIETY.

POSTPONED PAPERS.

1. *The* ALPS *and the* HIMALAYAS, *a* GEOLOGICAL COMPARISON.
By HENRY B. MEDLICOTT, A.B., F.G.S.

(Read June 5, 1867 *.)

CONTENTS.

I. Introduction.	III. Sketch of some Subhimalayan sections.
II. Notice of current opinions on Alpine sections.	IV. Suggested parallelism of the Alpine and Subhimalayan sections.

I. INTRODUCTION.

IN the summer of 1865, I obtained six months' leave of absence from India, after eleven years of continuous residence. I was anxious to make the most of the brief opportunity to bring my thoughts into relation with those of the working geologists of Europe. My best available means of doing this was to visit some well-known ground, and to study what had been written of it. For such a purpose I was most fortunate in being able to select the Alps. No region has been more explored and written about; and, as much of my own work in India had been upon certain portions of the Himalayan range, it had long been my desire to compare my sections with analogous ones in regions geologically classical. The opportunity was so brief and without prospect of renewal, that I thought it best for my purpose to take a rapid view of a large area, rather than attempt the close examination of any one locality. Accordingly I devoted one month to the outer Alps, between the lake of Constance and Grenoble,—the Molasse and its relations to the mountain-range being the points to which my attention was specially directed. Immediately upon my arrival in India, at the beginning of the cold season, I had to start into camp. It has only been since my return

* For the other communications read at this Evening-meeting, see Quart. Journ. Geol. Soc. vol. xxiii. pp. 322 *et seq.*

to Calcutta during the monsoon that I have had the opportunity of looking into the literature of Alpine geology ; and I now venture to offer the following paper as a small contribution to the subject.

The progress of geology has not been equal. The more attractive branches have been cultivated far beyond those that seem less attractive ; thus, as both must frequently appear before the public together, the effect is very incongruous. Such is the case presented in even the most recent works on the geology of the Alps. Alongside of the refined investigations of comparative palæontology, one finds stratigraphical features treated most loosely—from the point of view of assumption, and with little or no examination of evidence. The very language used in many cases would suggest that these structural phenomena were the performances of some uncanny mountain-sprites, rather than of forces or processes with which we had any chance of becoming acquainted. The mischievous effects of this are widespread ; besides shaking the scientific credit of the men who can issue such uncritical work, and hence suggesting doubt in the value of their more special work, a shadow of darkness is thrown over the whole science. Stratigraphy in these mountain-regions is still appealed to in support of notions that have long since been refused general acceptance in geology. It seems to be forgotten that stratigraphy is the foundation of geology, as, without the initial physical fact of sedimentary superposition, palæontology, as we know it, could have had no existence. It is surely very unwise of the students of this younger branch so soon to assume its independence, while many of the positions from which it now provisionally works are still unproved. This mutual development is not, indeed, likely to take the exact form imagined by M. Barrande, in his speculation on the relations of the *haute stratigraphie* to the *haute paléontologie*[*] ; but that the problem will one day or other be worked out, no true naturalist will doubt. For the present, however, neglect, not to say contempt, seems to have fallen upon stratigraphy among a large section of professing geologists. By some the word is even appropriated to a department of palæontology, to indicate merely the *habitat* of fossils : M. Marcou says[†], "En stratigraphie il n'y a encore à l'heure qu'il est, qu'un seul principe de vrai, de bon, d'utile ; c'est de voir avec la plus grande exactitude, tout ce qui se trouve dans chaque couche de roches." Elsewhere (p. 48) the same author seems to make orography the geological complement of his "stratigraphy," assigning England as the birthplace of the latter, and Switzerland of the former. It would seem preferable to leave the word orography, as indicating the purely superficial features, to the physical geographer ; and to use the term stratigraphy (in the same sense as M. Barrande) to mean the structure of the earth, the relations of rock-masses, as exhibiting the mode and sequence of events. If orography be used in this signification (as implying the *explanation* of superficial configuration), Switzerland has scarcely justified M. Marcou's dictum ; it has been the stumblingblock rather than the

[*] Bull. Soc. Géol. France, 2e série, vol. xi. 1853–54, p. 311.
[†] M. J. Marcou, 'Lettres sur les roches du Jura,' Paris, 1860, intr. p. 9.

guide to rational geology. M. Thurmann's* elaborate classification
of the structural features of the Jura seems to have led to no fur-
ther conclusion than that the contortions were produced by lateral
pressure.

One must have visited alpine regions fully to understand how in-
dispensable palæontology is to the field geologist. It would be all
but impossible to discover the structure ¡of many large areas (and
how much more so to assign the appropriate relative ages to the
several rock-groups !) without the sure criterion of the fossil remains.
But it must not be forgotten that this bare structure and these
relative ages are but a portion of the mere data upon which a geo-
logical history of the region is to be founded.

It has often occurred to me that geologists are guilty of a general
inconsistency in taking so little account of subsidence in the dis-
cussion of phenomena of disturbance. Subsidence is often intro-
duced to admit of the continued accumulation of deposits ; but,
to account for the disturbance of strata, upheaval and intrusion
are the agencies commonly appealed to. Yet in the most generally
accepted theory of geogeny, the dominant character is shrinking and
the consequent depression of the surface. The leading speculations
upon crust-movements have indeed proceeded from the point of view
of this theory; but I am now alluding to the lesser features of
disturbance—the dips and strikes which form the elements of actual
observation. If that theory be true, the features resulting from
depression should greatly predominate in the detail-structure of the
earth's crust. I am far from insisting that *à-priori* views should
regulate rigidly our interpretations of phenomena. It would, on
the other hand, be more in accordance with rational methods of
research that those views should be taken into account, if it were
only for the purpose of verification. In the case of the grand
cosmological speculation of Laplace, the study of the earth's structure
is almost the only direct test we can apply. The opposite course
has been adopted : not only have the suggestions of this theory been
disregarded, but the positive indications of mechanical laws have been
set aside to warp observations into agreement with our superficial
prepossessions. Many a scientific man cannot see a hill without
taking for granted that it has been upraised, and attributing all its
features to that process. In the particular case before us, the con-
tortion of the Molasse is to this day the accepted proof of the last and
greatest upheaval of the Alps. It can scarcely be necessary to say that
such contortions can only indicate yielding, and hence an equivalent
settlement of the mass from which the pressure is communicated.
Flexures may, indeed, accompany an upheaval ; but if so they must
be a negative element in the total ; and it is stepping beyond the
limits of legitimate inference to take them *primâ facie* as evidence
of upheaval. Such, however, is the only explanation offered of the
flexures of the Tertiary strata at the base of the Alps, no account
being considered necessary of the supernatural force demanded for

* Bull. Soc. Géol. France, 2ᵉ série, vol. ii. 1853, p. 41. I do not know if the
work of which this paper is but a prodrome, ever appeared.

so peculiar a process. The united efforts of expansion and gravitation seem to me unequal to the task. Is it not absolutely certain that any natural lateral force in the shell of our globe can be neither more nor less than a component of gravitation—of the centripetal force,—and thus that any consequent compression must indicate a total result in the same direction? I cannot pretend to speak with any authority on a question of pure mechanics; nor do I, in using the word "supernatural" attempt to dictate the impossible; it is, however, a maxim that definite scientific speculation should keep within sight of ascertained facts. The accepted interpretations of Alpine sections seem to me to transgress this maxim. I have not found any very circumstantial explanation of the upheaval appealed to in those accounts; but the alleged result seems to me to necessitate the conception of this mountain-mass as of a very acute wedge, discontinuous from the enclosing matter (like the bung in a barrel), driven outwards—not by any general expansive force, for such must act with equal or greater effect upon the contiguous matter, which (not being hooped down) would rise rather than be compressed, but by some peculiar force acting only on the wedge. The onus of discovering such a force must rest with those who have evoked it. I would rather suggest that these features of contortion be taken only for what they *primâ facie* imply—the sinking of the mountain-mass. Subsidence, or at least shrinkage, as exhibited by the compression of strata, is seen in every region of the earth. In these matters geologists seem to have retrograded from the views of Deluc and other early fathers of the science[*].

Actual observation has placed beyond doubt the fact of small, but rapid, elevation of large areas of the earth's surface. Long-continued slow rising is also an established fact. It is fortunate we have this information; for it were difficult to say what could be the positive *stratigraphical* evidences of upheaval. The burst-bubble performance, which is so largely accepted as accounting for the structure in the central regions of the Alps, is quite at variance with all we know of natural phenomena. As evidence of actual upheaval, the presence of marine deposits above the sea-level is, generally speaking, indisputable[†]. With reference to deposits not marine, a large correction must, however, be introduced into Alpine geology. The recently recognized power of rain and rivers to form extensive deposits at any level will no doubt remove the necessity for much of the prodigious rising and sinking hitherto demanded to account for such non-marine deposits, both in Posttertiary times and during the Molasse period.

[*] Bull. Soc. Géol. France, 2e sér. vol. vii. p. 54.
[†] The assumption of the absolute permanence of the sea-level (that its level has permanently maintained the same radial distance from the centre of the earth) has quietly taken the position almost of a postulate in geological induction. The notion is inconsistent with any progressionist doctrine, essentially so with Laplace's theory. A very grave obstruction may thus be introduced into the discussion of questions where very remote conditions may be concerned, as in this question of mountain-structure.

From what I have already said, it will not be expected that I can attempt to add to our knowledge of the Alps by more detailed observations of their rock-features. My suggestions must derive their force from other regions. I saw enough of the Subalpine ground to assure me that it presents a close parallel in geological history to the Subhimalayan region. The original and the superinduced characters in the two are strikingly similar. Whatever mode of explanation suits the one must fit the other. The interpretation I have put forward* of the Subhimalayan rocks, based perhaps upon sections more favourable for observation, differs so widely from what I find written about the Alps, that I am induced to call attention thereto. It will be necessary first to indicate, by reference to authors, what the views are to which I would take exception. I will, after that, sketch the results of my observations in the Himalayas, and finally indicate their possible application to the Alps.

II. NOTICE OF CURRENT OPINIONS ON ALPINE SECTIONS.

The name of *Molasse* has long since been extended, from its original application to a particular soft sandstone, to the whole series of strata of which that sandstone forms a prominent member. The series has more recently been divided into several groups; but the same general term is still conveniently applied to all. They are of Middle Tertiary age. The home of the Molasse is along the northern base of the Alps, where it occupies the great valley of Switzerland, between the Alps and the Jura, extending eastwards through the Bavarian plains to Vienna. To the south-west, in Savoy, where the Jura-range becomes confluent with the Alps, the Molasse appears in the longitudinal valleys, along the continuation of the main valley. The actual area of these Miocene rocks represents approximately the original limits of deposition; and the strata are throughout strongly unconformable with the adjoining formations. In a zone along the base of the Alps, and several miles in width, the Molasse strata are more or less intensely disturbed, while beyond that zone they maintain their original horizontality.

Very conflicting opinions still maintain their ground regarding the bare facts of the Molasse section, both as to composition and as to the features of disturbance. One generally accepted feature is the continuous anticlinal flexure, observing an approximately medial position in the zone of disturbance. M. Studer described it in 1838†. In the same memoir a general descending order of succession is given —Nagelfluhe (conglomerate), molasse, and mottled argilaceous strata. There would thus be an ascending section up to the main line of junction at the base of the mountains, where the author speaks of these rocks as abutting against the Secondary formations of the Alps. The Rigi is referred to as typical of the common mode of contact, the strata there passing under the Cretaceous system. This is explained by the sliding of the older rocks on the top of the younger. The

* Mem. Geol. Surv. India, vol. iii. pt. 2.
† Mém. Soc. Géol. France, 1ᵉ série, vol. for 1838, p. 379.

figured section makes them apparently in parallel superposition, each
being in its normal order. In another paper[*] M. Studer accounts
for the great accumulation of the Molasse by subsidence along a
fissure at the base of the Secondary mountains.

In his well-known paper on the structure of the Alps[†], Sir R. I.
Murchison adopts the most extreme views regarding the interpreta-
tion of the rock-disturbances. The great masses of subalpine Nägel-
fluhe in the Rigi and the Speer are not taken to be inverted (although
MM. Studer and Escher de la Linth were the author's companions
in these regions), but the junction of the Molasse with the moun-
tains is spoken of as an enormous fault, whereby the topmost Nagelfluhe
is brought into contact with low rocks among the older formations[‡].
The elevation and dislocation of the Molasse is described as demon-
strably sudden, and as proving that the crust of the earth was then
affected by forces infinitely greater than now. There is no attempt
to specify the nature of the disturbing force ; it is not even referred
to the elevation of the Alps ; but such a subsequent upthrow of the
older rocks is almost necessarily implied in the word "fault," as
applied to the junction of the Molasse with the mountains.

M. Rütimeyer[§] gives an account of the intricate section at Ral-
ligen. The figured section seems quite impossible in its details ; but
it exhibits some interesting facts, the abrupt appearance of much
older strata at the base of the Cretaceous rocks near the junction,
and the occurrence of a narrow band of crushed lower Molasse
against which the Nagelfluhe abuts at a moderate inclination.

M. Lory[||], in his sections of the range of the Grande Chartreuse,
shows a fact of importance. In some of the great flexures (Vallée
de Proveysieux) the Molasse is represented as so parallel to the
Cretaceous strata on which it immediately rests, that these must
have been approximately horizontal at the time of deposition of the
former. Sections of other authors in the same region (close to Annecy)
give a very different relation.

In a memoir on the North Vorarlberg[¶], Escher de la Linth expresses
his views upon the general sequence of geological events in the Alps.
The Nagelfluhe is described as dominating along the zone next the
Alps, and as being there equivalent to finer deposits more to the
north. For several miles to the north of the boundary with the
Flysch, the underlie of the rocks is south-easterly ; but in this zone
there are several repetitions of the strata by folded flexures. The
figured section (No. 16) is scarcely consistent with the text ; at the
junction, the critical point of all, there is no saying whether the
Nagelfluhe is a top or a bottom band, or what its true relation to the

[*] Neues Jahrbuch, 1850, p. 221.
[†] Quart. Journ. Geol. Soc. Lond. 1848, vol. v. p. 157.
[‡] The use of the word *inverted*, in the paper quoted, is confusing : being
sometimes applied, in its usual English acceptation, to strata turned upside
down, it is more frequently used in the more arbitrary sense of dipping in a
wrong direction, being apparently put for the German "*wider-sinnig*."
[§] Neue Denkschriften, Zürich, vol. vii.
[||] Bull. Soc. Géol. France, vol. ix. 1851–52, p. 226.
[¶] Neue Denkschriften, Zürich, 1853, vol. xiii.

older formations may be, besides that of present apparent conformable succession. The author attributes all this contortion to the revolution which gave to the limestone-range its present aspect: much of the Vorarlberg was dry land during the Flysch period, and after it the whole mountain-region became dry land. The greatest revolution here occurred after the Molasse,—in proof of which M. Escher adduces, first, the great local contortion of the Molasse; secondly, the intimate connexion of the Molasse and the limestone mountain, so that the present position of both must be the result of the same effort; and, thirdly, the fresh and well-defined relation of the mountain-contours to the position of the strata, and the correspondence of these features throughout the whole mountain-section. In short, the abruptness and comparatively good preservation of the Alps seems to indicate their youthfulness! The independence of the outer mountain-fringe, and of the indented boundary of the central masses, suggests how much greater the force must have been which produced the former. Yet the general similarity in the features of disturbance proves both to have been acts of the same long process.

M. Rozet[*], from the slight disturbance of the Molasse in the French Alps, considers that the greatest dislocations of the mountains occurred between the Eocene and Miocene periods.

In the Eastern Alps we find M. Stur[†] adopting the usual theories. After the Eocene period a great disturbing force broke up the hitherto little-troubled regular succession of formations, producing the fan-structure and the transverse valleys. After a succession of subsidences for the deposition of the Neogene strata, there came the last great fissuring and upheaval, the floods occasioned by which produced the diluvium.

M. Brunner[‡] makes a great effort at a rational improvement upon the usual mode of explanation, but seems to involve the question in more difficulties and apparent contradictions. Thurmann's explanation of the flexures of the Jura mountains, by the Alpine upheaval, is rejected on account of the intervening area of undisturbed Molasse; and similarly the folds of the Stockhorn cannot be due to Alpine upheaval, on account of the Flysch of the Simmenthal. This observer rejects the mode of action called plutonic, and localizes the cause, finding adequate force in the expansion due to crystallization. Still the lateral displacement is connected with the upheaval. The actual Molasse boundary is not considered a shore of that period; the rocks sre said to be broken sharply at the junction. The author accounts for what he calls the *abnormal* projection of the boundary at the Stockhorn, and the absence of Nagelfluhe, by the greater lateral sliding of the mountain-mass at this spot. For the four shocks usually reckoned for the production of the Alps M. Brunner substitutes one long upheaval, commenced after the Lias, and continued uniformly until after the Molasse.

    [*] Bull. Soc. Géol. France, vol. xii. 1854–55, p. 204.
    [†] Sitzungsberichte der k. Akad. Wien, vol. xvi. 1855, p. 477.
    [‡] Neue Denkschriften, Zürich, vol. xv. 1857.

M. F. v. Hauer[*], in his section of the eastern Alps, says that the first great upheaval, involving contortion, occurred after the Lias; and he seems throughout to attribute contortions and valley-formation to such agencies.

In his paper on the Tertiary rocks, M. Lory[†] uniformly attributes the contortions of the Molasse to the upheaval of the Alps.

M. Kaufmann's paper[‡] on the Subalpine Molasse is the most detailed I have seen. He traces three axes of flexure throughout his entire area—a synclinal between two anticlinals. The inner anticlinal is a folded flexure; and thus the flanking belt of hills, at the base of the great range, is sometimes partly composed of inverted strata as in the Beichlen: the great hills of this zone (the Rigi and the Speer) are south of the inner anticlinal; and therefore the strata are in their normal order of superposition, as the contact-rocks must be throughout. M. Kaufmann, however, altogether avoids the actual junction; the inner rocks do not appear on any of the figured sections. The historical sketch given by this author is peculiar. A continental elevation is distinguished from that confined within the mountain-range. During that elevation great erosion of the Molasse area took place, leaving hills of Nagelfluhe in their present approximate position. The lateral pressure, subsequently induced by the mountain-upheaval, produced the lines of flexure along the lines of erosion, as lines of weakness. Although M. Kaufmann thus seems to invert the usually accepted order, he is in advance of most Alpine geologists in even recognizing the intimate connexion between contortion, denudation, and valley-formation. During the mountain-upheaval, it is considered that the Molasse area must have suffered depression, to help to account for the actual superposition at the contact. Like all the preceding writers, M. Kaufmann seems to think it necessary to account for the present irregularities of the line of boundary as due to disturbance—although no one offers any reason for assuming it to have been at any time straight, unless in so far as such an assumption is implied in the assumption of a great line of fissure.

M. de Mortillet[§], after describing many facts implying how partial in extent and in influence great changes of level may be, conforms fully to the current opinion. The last great rising of the Alps is described as having taken place at the close of the Miocene period; this upheaval traced out the valleys as we see them, rock-basins and all. It was the last violent movement.

M. Favre[||] would seem to connect the origin of the Salève mountain with that of the main anticlinal in the Molasse.

In M. Gümbel's large work on the Bavarian Alps[¶], notwithstanding the great labour expended, the stratigraphical question does

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[*] Sitzungsberichte der k. Ak. Wien, 1857, vol. xxv. p. 253.
[†] Bull. Soc. Géol. France, 1857–58, vol. xv. p. 40, and vol. xvi. p. 823.
[‡] Neue Denkschriften, Zürich, vol. xvii. 1860.
[§] Bull. Soc. Géol. France, vol. xix. p. 849 : 1861–62.
[||] Bull. Soc. Géol. France, vol xix. p. 928 : 1861–62.
[¶] Geol. Beschreibung des bayrischen Alpengebirges und seines Vorlandes. Gotha, 1861.

not seem to be placed upon a better footing. The diagram section
figured on pp. 679 and 757 is irreconcileable with itself; the lowest
beds of the series, next the main junction, as numbered and described,
are shown at the top of what must be (according to the lines of
stratification) a normal ascending section. There are other similar
discrepancies in the same section. The evidence given (p. 694) that
the lowest beds do occur next the junction is far from convincing.
There is much variety shown in the actual sections taken at different
points of the junction, inversion being by no means the rule. The
irregularities which occur in the line of boundary, generally near a
main valley, are explained in the same arbitrary manner as by M.
Kaufmann and others—by the horizontal displacement and projec-
tion of the older rocks at these points of transverse fracture. The
sequence of formations is represented to have gone on regularly up
to the Cretaceous period, the younger Cretaceous rocks resting
transversely upon all. The Nummulitic deposits stretched, up fiords,
deep into the Alps, the coal-beds of Häring, in the Inn-Thal,
showing that the limestone Alps were then as high as now. A
little further rise of the coast defined the basin of the Molasse.
The warm character of the Neogene flora precludes the conclusion
that the Alps (? the central Alps) were as high as now. Hence this
altitude must have been attained since : as collateral evidence of this
" Katastrophe " the author points to the contortion of the Neogene
strata. The similar preceding alterations of level can only be
looked upon as precursors of this " Haupthebung." It is remarked
that this period corresponds with that of great volcanic eruptions in
other regions. The state of the Alps during the Molasse period is
compared (p. 870) to that of the present Jura and Swartzwald ; then
came the " Hauptkatastrophe." Erosion and disintegration after-
wards completed the present configuration. It would seem, however,
that considerable depression can occur without any remarkable
stratigraphical results, the inundations which produced the Loess,
M. Gümbel supposes to have been caused by sudden sinking of the
snow-clad mountains. Were not M. Gümbel's history full of
anomalies, one might suppose that the events just indicated can
scarcely have appeared to the author so violent as the language and,
indeed, the alleged facts seem to require ; for he makes the excellent
suggestion (p. 854) that some shelves of débris, now found in the
inner Alps separated from the present watercourses, may belong to
the Molasse period. The fan-structure of the central masses is
accounted for by the protrusion of the mountain-core. The pre-
vailing inward dip in all the fringing mountains is attributed (p. 855)
to the tendency of the strata to range themselves at right angles to
the upward and outward pressure—an explanation which seems to me
to lead to a result the very opposite of that required. To render
possible the contortion in the Tertiary zone, M. Gümbel considers it
necessary to suppose the resistance of a now departed mountain-
ridge somewhere in the Bavarian plains.

Professor Ramsay, in his paper on the glacial origin of lakes[*],

* Quart. Journ. Geol. Soc. Lond. 1862, vol. xviii. p. 185.

gives an ample refutation of the notion, universally adopted by con-
tinental geologists, of the fissuring by elevation as an origin for
valleys, transverse or longitudinal; his argument applies by impli-
cation against accepting contortion as evidence of elevation. The
contortion of the Miocene strata is, however, accepted as proof that,
after the Miocene epoch, the rocks of the Alps were much disturbed,
sufficiently so to alter the drainage-system in all its details. In the
Molasse itself the inversion of the rocks of the Rigi is quoted as a
measure of the action.

Sir Charles Lyell, in his 'Antiquity of Man' (p. 309), adopts
generally the views which connect the disturbances of the Molasse
with, and as proof of, the last series of movements to which the Alps
owe their present form and internal structure, dissenting from those
views so far as they include the production of the lake-basins.
He combats, I think effectually, Professor Ramsay's theory of the
formation of the great Alpine lakes by glacier erosion; while at the
same time (in assigning unequal subsidence of large areas as the
main cause of these lakes) he introduces glaciers as an almost
essential adjunct, to prevent silting up *pari passu* with the subsi-
dence. The absence of lakes in non-glacial mountain-regions is
accounted for in that way. In appealing to the undisturbed, yet
præglacial, lacustrine deposits on the lake of Zurich against the
theory of Prof. Ramsay, Sir Charles Lyell seems to overlook that
this evidence tells with as great force against the use he himself
makes of glaciers in the production of those lakes; for the lake of
Zurich must by his process of formation have attained its maximum
extension and depth when the deposits of Utznach and Dürnten
were formed, *i. e.* before the glacier-period.

The Molasse does not come within the range of Professor
Theobald's recent work on the Grisons *; but the author would
seem to allude to the contortions of those rocks when he says (p. 7)
that only on the north did the upheaval of the Alps find an obstacle,
in the earlier formed crystalline mass of the German Mittelgebirge.

In M. Heer's valuable work on the geology of Switzerland †, there
is scarcely any tangible allusion to physical geology. The author
seems to adopt the current opinions upon the last great upheaval of
the Alps, subsequent to the Molasse period.

'Der Gebirgsbau der Alpen' ought to be an exact complement
and suitable companion to 'Die Urwelt der Schweiz.' M. Desor's
work ‡, however, in no real sense fulfils this expectation; there is
not a single section in it, nor anything like a critical matter-of-fact
discussion of Alpine rock-structure. The history of the Alps is
divided into two great periods, before and after the last mountain-
upheaval. From the early Prælias land the centre had progres-
sively risen, but unequally and with oscillations. On the south the
Pliocene deposits suffered the same disturbances as the Miocene; so the

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* Geol. Beschreibung der N. O. Gebirge von Graubünden. Bonn, 1864.
† Die Urwelt der Schweiz. Zürich, 1865.
‡ Der Gebirgsbau der Alpen. Wiesbaden, 1865.

" Haupthebung," the last " Krisis," which was as great as all the
others put together, must have been at the end of the Tertiary periods.
M. Desor traces all the great features of the Alps to this time—folds,
inversions, *combes*, and *cluses*, and the general uniformity of dips
throughout the whole section.   The Rigi and the Speer are men-
tioned as instances of inversion in the Molasse, on the authority, I
believe, of M. Studer's more recent observations.

Such is the latest and most tragic history of the Alps.   It fully
confirms the statement with which I started, that a school of geology,
obsolete elsewhere, still holds its ground in those mountain-regions.

Any general notice of the geology of the Alps must be altogether
deficient without mention of the latest opinions of M. Studer, whose
great work on the geology of Switzerland is the acknowledged
authority.   I have not had access to this book.   My object, however,
has only been to show, by sufficient references, what is the generally
received view regarding one or two important features of Alpine
geology.   I have omitted no available source of information ; the
works of most of the best-known observers have been consulted ; and,
from the frequent allusion made by other writers to M. Studer, I
am pretty confident that his views upon those points coincide more
or less with what I have represented.   He is, I believe, the authority
for the inversion of the rocks in the Rigi and Speer.

The opinions to which I would draw attention, as universally
applied to the Alps, are the abnormal (faulted) nature of the actual
boundary of the Molasse with the rocks of the higher Alps, and the
explanation of this, as well as of the contortion of the inner zone of
Molasse, by the direct upheaval of the main mountain-mass.   In
almost all the works referred to there may be found passages to the
effect that all the features of the Alps are the result of one long-
continued action.   These professions can be little more than nominal
concessions to modern views ; at least every special explanation
and many of the alleged facts seem to me to be essentially incon-
sistent with such views.

III. Sketch of some Subhimalayan Sections.

There is a very striking similarity between the sections along the
southern base of the Himalaya and the northern base of the Alps.
One can scarcely doubt that the histories of the two regions have a
corresponding agreement.   I must refer to my memoir on the Sub-
himalayan rocks of North Western India * for a detailed description
of the sections ; I can here only point out some leading features.
The clays, sands, and conglomerates of the Sivaliks are undistin-
guishable in hand specimens from those of the Molasse.   In both
regions the coarser deposits prevail towards the top.   The distant
hills on the south of the Gangetic plains form only nominal repre-
sentatives of the ranges which bound the great valley of Switzerland
on the north ; and the ancient alluvium forming those plains
conceals completely the southern extension of the Sivalik strata
beyond the limits of a narrow zone fringing the mountains.   Within

* Mem. Geol. Survey of India, vol. iii. pt. 2.

this zone the rocks always exhibit more or less of disturbance, very often to an extreme degree.

There are two well-defined groups in this Subhimalayan zone. Along their northern boundary the Upper Sivalik strata abut against lower beds of the same Subhimalayan (Tertiary) series, of the middle (or Nahun) group. These latter beds form a narrow band of variable thickness, but rarely, if ever, absent, separating the true Sivaliks (the strata which yielded the Fauna Sivalensis) from the much older rocks of the higher mountains. Sir Proby Cautley has identified the rocks of the Nahun band with the beds at the outer base of the Sivalik hills, where they seem to be regularly overlain by the younger Sivalik strata *. The collection of fossils from the older beds, which might have thrown such light upon this stratigraphical break, has been lost since its transmission to England ; indeed I am told, by the distinguished donor, that this misfortune has befallen it since the consignment of the collection to the vaults of the British Museum †. Even without the palæontological facts, the relation I have described of the Sivalik and Nahun groups is remarkably analogous to that of the Neogene and Oligocene groups of the north-eastern Alps.

In one portion of the north-west Himalaya we find a remnant of a much older group of Tertiary rocks ; the bottom beds are the well-known Nummulitic strata of Subathoo. They are overlain transitionally by sandstones of the regular Molasse type, only thoroughly indurated, like the Flysch sandstones of Appenzell. By position this group identifies itself with the rocks of the outer edge of high mountains, rather than with the true Subhimalaya, just as do the corresponding rocks in the Alps, thus completing the analogy of the sections with almost startling exactness.

The Subathoo group rests high up on a base of the slates forming the mountains, upon a denuded surface of which it had been deposited, both rocks being now seen folded in the same contortions. The younger groups of the Subhimalayan series (Sivaliks) only appear at the outer base of the mountains, and the junction is as apparently abnormal as anything seen in the Alps ; the dip of the younger rocks is almost invariably towards the contact, the plane of which underlies to the north, thus producing actual, though not parallel, superposition of the older rocks. All the arguments as to prodigious faulting &c. that have been applied to the Alps would be just as applicable here.

A very brief inspection of the Sivalik rocks made me averse from the supposition of any great change in the features of the surface since the time of their formation. There is at once apparent a most

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* Journ. Asiat. Soc. Bengal, vol. iii. 1834, p. 528.

† The more we see of these Sivalik rocks, the more does our admiration increase for the discoverers of the Fauna Sivalensis. I failed to find fossils either at Nahun or at the Kalawalla pass ; and within this last year Captain Godwin-Austen, who has much experience as a collector, incited by my account of the difficulty and of the interest attaching thereto, spent some time at Nahun searching for fossils, but without the smallest success.

marked correspondence between the distribution of the accumulations of conglomerate and the position of the actual river-gorges of the mountains; even in front of some of the lesser streams, with very contracted drainage-basins, this limitation is well marked. Yet these conglomerate masses are often as thick and at as high angles as those on the Rigi and the Speer.

It was along the junction of the Sivaliks with the Nahun group that I found the sanction for the explanation I was disposed to apply to the main junction of the Subhimalaya with the older rocks of the high mountains. That line of contact of the two younger groups is mostly concealed along the inner slopes of those longitudinal valleys known as "dúns." For about twenty miles midway in the space between the Jumna and the Sutlej the Sivalik hills are confluent with those of the Nahun band; and the junction of the groups can here be followed without a check. The character of it is most constant, and uniformly of the type already noticed. The conglomerates dip at various angles, high and low, against the bottom beds of the Nahun band; they seem to go under, or to be buried in, the older rocks, the plane of contact actually underlying to the north. Here then, again, we have a *primâ facie* case of reverse faulting, of lower rocks slipping up over younger ones. A doubt of this is first raised by the fact that the conglomerates contain much débris of the Nahun rocks. There is, however, an actual section which seems to render impossible the supposition of any faulting whatever: on the same boundary, and within half a mile of a grand section of abnormal superposition, we find the same conglomerate beds dovetailed into a serrated steep denuded surface of the same Nahun beds; and, further on, the younger beds broadly overlap the older. The process of formation revealed by these sections is, that the Upper Sivaliks were deposited against a steep denuded edge of the older group, the present inverted plane of contact being due to subsequent lateral pressure, which has not otherwise displaced the original boundary by any vertical relative motion of the masses in contact.

In spite of the great unconformability I have just noticed along the inner boundary of the Nahun and Sivalik groups, it would seem, according to the identification made by Sir Proby Cautley, as already noticed, that these same groups at the base of the Sivalik section, some miles to the south, are in apparently unbroken sequence, both being now much disturbed. Such a fact would be most convincing proof of the exceeding gentleness and partiality of the process of disturbance. Should any doubt hang over this point of evidence owing to the unconfirmed and originally incompleted palæontological observations upon which it rests, there is sufficient independent proof of the same inference as to the nature of the disturbing process, in the permanence of Præsivalik stream-courses. If this were only observed in the case of the great gorges of the higher mountains one would scarcely be surprised. These tortuous gorges are manifestly the work of rivers; but one has to encroach deeply upon geological time for the accomplishment of such results. In

the case of those great features, moreover, one can imagine very considerable violence of disturbance to occur without causing any alteration. Neither of these pleas suggests itself in the case of such streams as the Guggur and the Batta, the springs of which are not further in than the first ridge of the mountains.

The most apparent instance of the feature under notice is found in the course of the Sutlej. This mighty torrent debouches upon the plains at a point where the zone of the Subhimalayan rocks has become greatly widened, owing to the retreat northwards of the mountain-range; thus, before it reaches the outermost zone of the Sivaliks, the Sutlej has run for many miles through comparatively low hills of soft rocks of Lower Sivalik or Nahun type. At Bibhor the river cuts the last of these inner ridges; and on the outer flanks, on both sides of the stream, there are massive beds of coarse conglomerate, of boulders such as only occur in the main river-channels. These beds are now raised to the vertical; and in both directions along the strike these conglomerates pass gradually, within a few miles, into the ordinary sandstones. The presumption from such a coincidence seems irresistible, that the Sutlej itself had deposited these banks of boulders on the spot where it still flows. Whatever view one may take of the precise form of the contortions which now exist in these strata, their magnitude is unquestionable; yet, from the circumstances just noticed, the conclusion would seem unavoidable that they were produced at the very surface, and so gradually that one can imagine the process inappreciable to contemporaneous observers, had any such existed at the time.

Although the same detailed evidence is not traceable with regard to the main junction (that of the Lower Sivaliks, or Nahun band, with the slaty rocks of the mountains), it is certainly most reasonable to apply to it the same interpretation as was proved in the less-obscure section of the more recent boundary, and because whatever features are seen in the former are common to both. I consider that the older rocks had attained their present relative elevation before the deposition of the Lower Sivaliks—that the present contact of these rocks is the original one, only thrown out of its normal slope by the yielding of the softer and less-weighted rocks to lateral pressure.

The longitudinal irregularities in both the lines of boundary described are as numerous and as abrupt as those noticed in the Alps. The coincidence between them and the great river-gorges is quite accidental, there being more exceptions than examples of such a rule. I could not observe a shadow of evidence for these steps in the boundary of the mountains being due to cross faults or transverse fissures. On the contrary, I have always found them connected with local variations of strike, or of composition of the rocks, such as predetermine the irregularities in every process of denudation. Thus observation here seems to coincide with general considerations of terrestrial physics in separating, or even opposing, the operations of elevation and of contortion, the latter being altogether subsequent. That the contorting force in the case before us came from the

mountain-region no one would question; and no cause seems so
natural as the simple one of gravitation.   However puny any
mountain-range may be in comparison to the mass which supports
it, no grain is without its effect in maintaining the equilibrium.
The theory of M. de Beaumont affords a plausible expression for
such a process as I would suggest—a tuberance (bossellement) is pro-
duced with a slowness due to the motive source upon which that
theory is founded.   This upheaval would be scarcely observable, and
would produce no structural change, until a limit of resistance was
reached, whereupon gravitation, which all along had been the proxi-
mate cause of the tuberance, would become partially localized as an
agent of subsidence, involving contortion.   Direct gravitation is sup-
posed to be the breaking force, not any rupture analogous to that of
the tension produced by the bending of a quasi-rigid mass.   Such
a process might repeat itself any number of times in the same region.

In this way one might arrive at the apparent paradox, that the
structure of true mountains (those which are in an especial manner
regions of disturbance), from core to base, is the immediate result
and the record of subsidences. And, indeed, that commonest feature
of mountain-structure (the convergence of dips to central lines)
points directly to such a supposition.   Any attempt I have seen to
connect such a result directly with an elevatory force has been un-
satisfactory to my mind.

A force such as has here been supposed to produce contortion along
the outer zone of a mountain-range might not be simply a lateral force.
The partial sinking of the central regions might generate an elevatory
motion at the flanks.   The mechanical result in this position would
be variously apportioned to each of these forces according to the
circumstances of resistance.   The elevation which brought the
Nahun belt under denudation may have been of this kind rather
than connected with a general elevation of the whole mountain-
region.

From the foregoing explanations it will be evident that I con-
sider, first, the present contact of the Sivalik formation with the
mountains to be the original one, modified only by pressure without
relative vertical displacement; secondly, that the sinking of the
mountain-mass is the proximate cause of the contortions of these
Tertiary strata.   The annexed diagram section is an attempt to
exhibit, *with a minimum of contortion,* the explanation I would give
of the observed features of Subhimalayan disturbance.

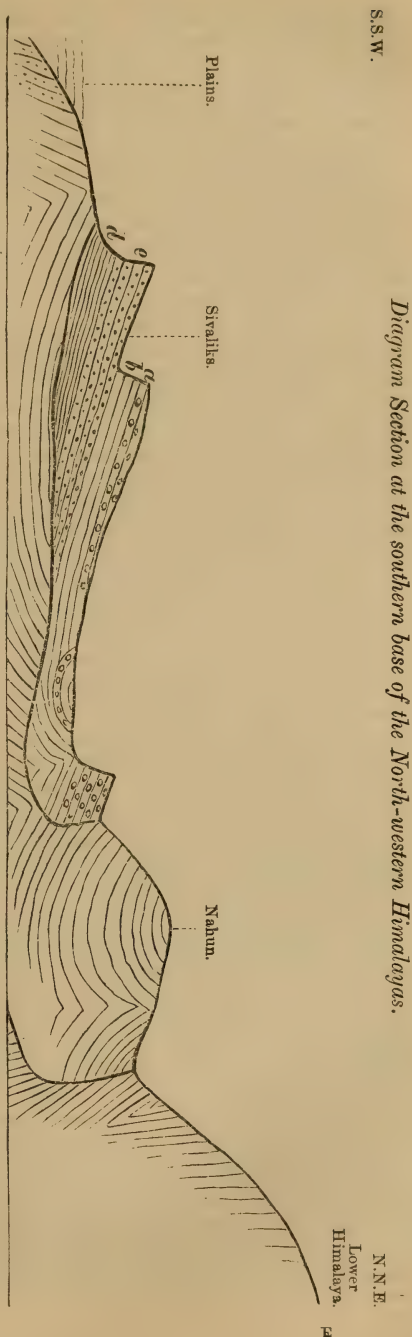### IV. Suggested Parallelism of the Alpine and Sub-
himalayan Sections.

Any attempt to apply circumstantially to the Subalpine sections
the interpretation I have offered for those of the Subhimalayan
region must be left to those who can visit the ground.   Adaptations
and modifications will be necessary, which can only be made out on
the spot.   There are manifest differences of orographical conditions
in the two regions, that could not but entail corresponding modifi-
cations in the results of a process such as I have supposed; and we

are not yet in a position to say deductively what these should be. The descriptions I have been able to examine are so wanting in detail upon the crucial points of the section, that I can only make vague identifications of parallel features.

The great anticlinal throughout the zone of disturbance in the Molasse would seem to find its counterpart in the Sivalik Hills. Throughout the whole North-west Himalayas these flanking hills are connected with an anticlinal axis, which generally runs along their southern base, the southern limb of the flexure having been denuded and covered by detritus.

The remnant of bottom beds of the Molasse series, so frequently found along the main boundary, between the Nagelfluhe and the Secondary rocks of the mountains, may be the physical equivalent of the Nahun band. As far as I can make out, it is upon the presence of these remnants that the supposition of inversion of the younger rocks at the contact has been founded, and extended to such sections as those of the Rigi and the Speer; but if my conjecture be correct, this would be unnecessary and erroneous. The denudation of the Lower Sivaliks consequent upon elevation, which in the Subhimalayan region was arrested well short of the mountain-

Diagram Section at the southern base of the North-western Himalayas.

S.S.W.

Plains.

Sivaliks.

Nahun.

Lower Himalaya.

N.N.E.

E

slopes, may in the Subalpine region have proceeded until there were left only detached remnants of the upraised Lower Molasse, which were saved from total removal by the encroaching deposition of the torrential detritus forming the Upper Molasse. Subsequent compression coincident with a sinking of the mountain-mass, which also seems to have gone to greater lengths in the Alps than in the Himalayas, might in such a case obliterate any clue to such an original relation. The necessity for suggesting this interpretation is the more surprising, since almost all Alpine geologists agree that the actual boundary of the Molasse is approximately in the position of the original limit of deposition. None state explicitly what is supposed to have become of the original contact.

The much debated question of the formation of the great Alpine lakes at once finds a place in the hypothesis I am proposing. This hypothesis assimilates the main feature of the explanation given by Sir Charles Lyell, as already noticed, and is free from the discrepancy I have pointed out in that explanation. The presence of these lakes is corroborative evidence of the sinking of the mountain-mass and the rising of the fringing zone, of which more direct proof has been sought in the structural features. I think that the formation of these lakes was more or less coincident with the contortion of the Molasse, and with the concurrent partial elevation of the zone at the base of the mountains, both results being due to the depression of the central region. A period of continental elevation, such as the tuberance of M. de Beaumont's theory, succeeding to a period of tranquillity, would have arrested the deposition of the Molasse, and brought on a period of denudation, just as was supposed by M. Kaufmann. The great valleys then received their final clearing out, preparatory to their conversion into lake-basins. In due time depression of the culminating regions of elevation, and compression, with reflex partial rising of the border-zone would supervene. Although adopting the maxim that the original main drainage of any area of elevation must be transverse to the axis of that area, since any such drainage must *pari passu* develope secondary drainage, transverse to itself, and therefore longitudinal with reference to the axis of elevation, one may admit with M. Kaufmann some small influence to these secondary lines in guiding the lines of contortion (which are essentially longitudinal) when the compressing action began to operate. The chief objection to this mode of relation of the actual general coincidence of these features is, that the regularity and continuity of the lines of flexure seem incompatible with so very accidental and superficial an influence as that of secondary lines of drainage.

It may be said that the Himalayan parallel fails to support me here ; there are no great lakes along the base of this range. Sir Charles Lyell has suggested that the absence of glaciers in the subtropical latitudes may account for the want in that position of lakes analogous to those of the Alps. It might have been known from the first that this removal of an admitted obstacle to his theory was of little avail ; for alluvial flats holding the place of the lakes in the

main gorges of the mountains (for the prevention of which alluvial deposition glaciers were admitted as secondary though almost essential agencies in the hypothesis) would equally well attest the action of the principal agency appealed to. Alluvial flats of this nature do not exist in the Himalayas; the great rivers are torrential throughout their entire course to the plains. It is evident, however, that the production of such lakes is a very non-essential result of the whole process now under consideration, and contingent upon a number of circumstances, in degree and in kind. All other conditions being alike, if in one case the erosion of the valleys were much more complete than in the other, the same relative movement would produce lake-basins in that case, while there could be no such result where the fall of the main drainage was very steep. Or, the same amount of vertical movement, equally efficient for the structural results required, may, from unseen influences, be very differently distributed in two cases; the central subsidence might be localized at and about the centre, with little or no rise along the flanks. By some such plausible modification as this, the great lake-basins of the central Himalaya may be the true analogues of the fringing lakes of the Alps.

I quite admit the force of the difficulty which induced Sir Charles Lyell to introduce glacial action as a subsidiary agent in the formation of the great Alpine lakes. I, too, should have thought that the accumulation of torrential débris would have kept pace with the formation of the basin. If the objection is sound, it quite upsets the supposition I have made regarding the age of the Alpine lake-basins. It rests, however, on a purely *à-priori* judgment, and cannot outweigh a fair accumulation of evidence on the other side. If that judgment proves unfounded we shall have acquired a provisional limit and gauge for the rapidity of the crust movement [*].

There is a well-known difficulty in Swiss geology that may, I think, be reduced by the supposition I have advanced as to the

[*] Some years ago Mr. H. F. Blanford applied this mode of explanation to some rock-basins in the Nilghiri Hills. See Mem. Geol. Survey of India, vol. i. pp. 241–243: 1859.

Although I have attempted to substitute another explanation for that given by Professor Ramsay of the formation of the great lake-basins of Switzerland, I fully assent to the power of glaciers to form rock-basins under certain conditions. An observation I made in Switzerland removed a mistaken *à-priori* opinion that had until then stood in my way. The observation must be patent to many, though I have not seen it described; but as the mistaken notion to which I refer seems to have still greater currency (it is the principal objection urged against Prof. Ramsay's views in a recent presidential address to the Geological Society), I may notice the observation. Supposing a rock-basin formed and filled with ice, it is often doubted if there could be enough of tractive force, or even of *vis a tergo*, to exercise a scooping-action within the basin; it is thought that the upper ice would flow on, leaving that in the basin almost undisturbed. The little lake of Lungern lies at the outlet from the fine amphitheatre cut in the flanks of the Brunig. The rock-barrier is so steep and narrow that it has been considered worth while to make a tunnel fifty feet below the rim, for the sake of the land gained at the delta by the partial drainage of the lake. The precipitous upward face of the rock-barrier is thus admirably exposed; and it displays numerous deep and regular grooves, the unmistakeable marks of the action in question.

period of formation of the basins of the great lakes, thus strengthening the validity of that supposition. It is the composition of the bunter Nagelfluhe. May not the unknown débris of this deposit have been derived from the portions of the valleys now depressed out of sight? This is surely a more likely conjecture than that of MM. Escher and Studer (as quoted in M. Heer's work, ' Die Urwelt der Schweiz '), of a ridge of these peculiar crystalline rocks along the north base of the Alps, the remains of which ridge have since disappeared down a fissure, and been further put out of sight by the lateral sliding of the limestone-mountains! If the great lake-valleys were still exposed to observation, if this phase of the process of disturbance had not extended to so much greater lengths in the Alps than in the Himalayas, we might find in this peculiar débris evidence, of the same kind as I have noticed in the Sivalik rocks, for the permanence of the Præmolasse streamcourses.

There are a few insignificant lakes along the outer fringe of the Himalayas that are evidently due to movements of the kind we are supposing, since the actual valleys were carved out. The Kundulu lake, on the road from Roopur to Belaspoor, is the most typical of this kind. The old lacustrine, or at least alluvial, area about Belaspoor itself and that about Haut, north of Subathoo, are of like character.

Although not attaching the same importance as has been given by several Alpine geologists to the subtropical character of the fauna and flora of the Molasse, as deciding the low elevation of the Alps in that period, compared with their present state, I may point out that the series of changes I am supposing would embrace such a position. Even the known distribution of land and sea in the Molasse period would go far to account for the required difference of climate. It is evident, however, that, at the commencement of the continental elevation which has been supposed to have interrupted the accumulation of the Molasse, the central mountains may have been lower than now. The word *continental* as applied to elevation implies only slow movement, a large area affected, and perhaps no *abrupt* linear limitation to that area, such as would be the " bossellement " in M. de Beaumont's theory. The last condition implies a very decided line of maximum elevation, which is all we require for the point under discussion.

If the view I have attempted to illustrate should not prove in any sufficient manner explanatory, even of the Subhimalayan sections, it will not have been useless to discuss a supposition that is fairly plausible, and which therefore should not have been so ignored as it has been, to the best of my knowledge, in discussions of Alpine sections and of mountain-formation in general.

2. *On the* GEOLOGY *of the* PRINCES ISLANDS, *in the* SEA *of* MARMORA, TURKEY. By W. R. SWAN, Esq.

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S., &c.]

(Read June 19th, 1867 *.)

CONTENTS.

1. *Introduction.*—It was during a visit to Prinkipo, the largest of the Princes Islands, in the summer of 1864, that I first had an opportunity of studying the geological features of that island; and the discoveries I then made were of so interesting a character as to induce me to continue the examination of the remaining eight islands.

Before going into a detailed account of each island, I will here relate some of the chief points of interest met with, namely:—

(1.) The existence of a considerable tract of Devonian strata, partly fossiliferous, in several of these islands, of an age different from that of the beds of the Bosphorus, which latter I have already shown, in a former paper to the Geological Society †, to belong to the lowest of the Devonian series of the Rhine. Also the existence of the remains of " fish " in the above strata, and an ancient " coral reef."

(2.) That the rocks which form the remaining portions of these islands are trachytic, and of younger age than the Devonian strata.

(3.) That the trap rocks of these islands are of younger age than the trachytic.

(4.) That the quartz rocks, of which some of the islands are largely, and some entirely composed, are altered sandstones of Devonian age, which clearly explains the occurrence of similar quartz rocks on the Bosphorus, which are seen in the mountains of Bulgurlou and Tchemlidja, behind Scutari, and referred to by Mr. Hamilton in his ' Observations on the Geology of Asia Minor.'

Proceeding now with the descriptions, I shall take first the Island of Prinkipo, and then follow on with the other islands in the order of succession of the strata (and not according to their size), so as to make, as nearly as possible, a continuous narrative.

2. *Island of Prinkipo.*—This island is the largest in size of the group, being about two miles and three quarters in extreme length from N.E. to S.W., and about one mile in greatest breadth from E. to W. The mountains of San Cristo and San George, rising respectively to the heights of 450 and 650 feet above the level of the sea, divide the island into two almost equal parts from the north to the

* For the other communications read at this Evening-meeting, see Quart. Journ. Geol. Soc. vol. xxiii. pp. 327 *et seq.*

† Quart. Journ. Geol. Soc. vol. xx. p. 114.

south, the watershed being east and west. The strata, in like manner, take the same division, the northern portion being for the most part composed of volcanic rocks, and the southern of primary sedimentary deposits. Viewed at a distance, from the deck of the steamer, when approaching Prinkipo from the west, the most casual observer cannot but be struck with the great difference in the physical aspect of the two mountains; for while the soft trachytic rocks of San Cristo have been rounded into beautiful outlines by the action of the atmosphere, the hard quartzose rocks of San George have withstood the ravages of time, and stand out in rugged masses and conical peaks.

The strata are divided into:—(1) Volcanic or eruptive rocks, which may be subdivided into Trachytic and Trappean; and (2) Primary sedimentary rocks.

a. Trachytic rocks.—Commencing from the extreme north-eastern point of the island, at the village of Prinkipo, and passing along the western side by the Ville de Giacomo and Morton's Flour-mill, and thence beyond a little bay that lies south of the great promontory that juts out from the mainland to the west, the strata are composed of white trachytic rocks, of a feldspathic nature, in general soft, forming sandstones in part, which are composed then of siliceous crystals in a feldspathic paste, unstratified and jointed, the joints being further cemented by the infiltration of iron in many parts, colouring the face of the stone at the joints of a dark-red and blackish colour. There are extensive quarries opened out on these sandstones around the brow of the San Cristo Mountain, where the strata can be well examined; some of the quarries have a perpendicular face of from 40 to 50 feet; and the stone works into angular blocks, affording a very ordinary but durable building-stone of moderate hardness. No signs of stratification whatever are to be observed in these rocks. In other parts, the trachytes are composed of a soft stone, or kaolin, which readily decomposes, wherever exposed to the action of the atmosphere, into a very pure kaolin, capable of being used largely in the manufacture of pottery-ware. The joints being the harder substance in this latter rock, from the iron cement, are less decomposed than the body of the stone, and stand out in the sea-cliffs a complete system of network, of a dark-red colour.

In approaching the Primary strata the trachytes become more siliceous, and alternate with beds of quartz rock. Here also much brown iron ore has been deposited in the joints of the trachytic rocks, rendering them in part metalliferous, and changing their colour to a dark red. In the cliffs immediately to the north, a band of these metalliferous trachytes is exposed for not less than 70 yards in breadth, and most probably extends across the island at the line of junction of the volcanic and sedimentary rocks, as the ferruginous deposits are again met with on the north-eastern side, of which I shall have to speak presently.

Returning again to the extreme north-eastern point of the island, and going thence along the eastern coast, immediately after leaving

the village of Prinkipo, the white trachytes are again seen cropping
out with their red joints; then, continuing on for about 100 yards
further, we arrive at a narrow strip of Primary strata composed of
grey and purple shales and grey limestones, which continue along
the beach for a distance of about 450 yards, until the trachytes are
again met with in the cliffs, alternating with the Primary strata as
far as the Bay of San Nicolo, where they come in contact with the
quartzose primary rocks of San George, and end there.

Here again, on this side of the island, at the junction of the vol-
canic and Primary rocks, large deposits of brown iron-ore have taken
place, but in greater abundance than in the beds of the west coast;
and near the ruins of an ancient monastery, large quarries were
opened out on the ore, about 17 years ago, by the Turkish Govern-
ment, furnaces erected to roast it (to be afterwards used in the
blast-furnaces at Zeitunbournou), and magazines and houses for the
workmen built, at a great outlay of capital and labour. The whole
works were, however, abandoned again within a very few months
from the time of their commencement; and a large quantity of the
quarried ore is lying at the furnaces to this very day, just as when
the works were last in use. The ore does not occur in regular
veins or beds, but in irregular masses or bunches, at the joints of
the rock; and in one quarry the ore has been followed down to the
depth of 60 or 70 feet, and the mine abandoned in apparently poorer
ground. The rock enclosing the mineral is highly siliceous; and
this must have enhanced greatly the cost of production of the ore,
and was probably a chief cause of the works being abandoned.

Ascending the mountain from these quarries, the strata gradually
change their highly siliceous and metalliferous character until they
become again the ordinary soft white feldspathic trachytes devoid
of iron, which, along with the white sandstones above mentioned,
are the prevailing rocks of the northern portion of the island.

The phenomenon of ironstone in the trachytes of Prinkipo, at
their junction with the older strata, is curious, and, excepting to a
very limited extent in Chalki, does not occur in any other of these
islands; and this is in contradistinction to the trachytes of the Bos-
phorus, where deposits of copper-ore (pyrites) have taken place at
their junction with the Devonian strata behind the village of Seriyeri,
on the Roumelian side of the Bosphorus. These occur in small irre-
gular veins and bunches, of considerable pureness; and mines have
been opened in them for several years; but, from the imperfect mode
of working, they have not been successful as a speculation.

In one spot only in Prinkipo have I been able to detect the pre-
sence of copper; and this occurs at a trap dyke in the trachytes,
exposed to view in a small ravine to the east of Morton's Mill, where
the dyke, about 8 feet in width, and composed of white crystals of
feldspar and dark-green crystals of hornblende in a feldspathic paste,
is coloured light-green by the presence of copper. It is also dis-
seminated through the adjoining trachytes and quartz boulders in
minute green crystallized veins of carbonate of copper. This copper
is doubtless derived from water containing a solution of that metal,

percolating from the interior of the trachytic rocks by the medium of the trap-dyke; but whether the source is from veins, or otherwise, is at present unknown.

b. Trap rocks.—The trap rocks of the islands may be regarded as proved to be younger than the trachytes, from the fact just now stated of the former piercing through the latter near Morton's Mill. Trap dykes occur at many points of all the islands, but principally in the sedimentary strata.

c. Primary sedimentary strata.—I have already referred to a strip of Primary strata lying on the north-eastern side of this island; these consist, in an ascending order to the south-west, of :—

1. A band of grey limestone, in which I detected stems of Encrinites.
2. Purple and grey shales.
3. Thick beds of grey limestone, seen here and there cropping out from under ground for the most part covered.

The above strata, along their whole extent, are much disturbed by close proximity to the trachytic rocks, their general dip being to the west, and their range from north to south. Fine sections of contorted strata, on a small scale, are seen here, made doubly clear by the alternation of thin bands of grey and purple shales, which mark distinctly the effect of side pressure. They then extend as far as the ironworks mentioned above, and are succeeded by the trachytes for about 200 yards, to be followed for about 40 yards by yellow and whitish clays and thin bands of grey grit which dip to the south-east at their northern end, and N. 36° W. at their southern end, at a moderate angle. The primary strata now disappear entirely for about 350 yards farther, and come in again at the Bay of San Nicolo, where white quartzose rocks are seen alternating with the trachytes, and dipping due south at an angle of 60°. Passing now across the Bay, which is covered ground, the first strata seen in the cliffs, beyond the Monastery of San Nicolo, are quartzose sandstones dipping S. 15° W. at 30°, followed in an ascending order by :—

1. Claystones of yellow, purple, brown, and white colours, in part soft and decomposing.
2. A bed of brown conglomerate of quartz and shale, with black bands.
3. White quartzose rocks for about 200 yards.
4. A bed of mottled grey and purple large-grained sandstone, with small imbedded pebbles of quartz.
5. Thick beds of hard quartz rock, evidently stratified along with the other beds, and dipping S. 65° W. at 40°.
6. Small bands of a soft purplish shale between beds of quartz.
7. Thick-bedded white tabular quartz thence past a little pebbly bay to the extreme south-eastern point of the island, in which the stratification is distinctly visible, their dip being S. 45° W. at 40° at the furthest point.

Passing now along the southern side of the island, the same quartzose rocks are to be seen in bold and rugged cliffs until we arrive at a narrow band of fossiliferous strata forming a promontory near the south-western extremity. These consist, in an ascending order, of :—

1. Beds of claystone, soft and decomposed at their junction with quartz rocks.
2. Thick beds of grey subcrystalline limestone.
3. Bluish-grey claystone, containing true Devonian fossils, such as *Phacops* or *Dalmania punctata* (both coiled and straight specimens), *Orthocerata*, small Goniatites, and a large *Bellerophon*?
4. Dark limestone and purple shale.
5. Yellow soft clays, containing Brachiopoda, Encrinite stems, &c. much decomposed and not describable.
6. Grey shale contorted.
7. Green and brown claystone, hard, with small nodules of brown limestone, yielding an excellent stone for building-purposes and quarrying into large blocks.

Turning now along the western side of the island, these strata flank the quartz rocks for a few hundred yards, until they are cut off by them at an indent of the land, but are succeeded again a short distance further on by other fossiliferous strata, which are evidently a continuation of the series just described, and are seen in the cliffs in the following descending order. The distances given are not the thicknesses of the beds, but the measurement of the coast-line.

1. Soft rotten yellow shales for about 100 yards, forming the junction with the quartz rocks.
2. Thick and thin beds of grey limestone in grey and reddish shales for several hundred yards, fossiliferous, and dipping S. 65° W. at 60°.
3. Beds of grey limestone in purple shales, containing large and small *Orthocerata*, Trilobites of the genus *Phacops* (both straight and coiled, and very similar to *P. bufo* of the Hamilton beds, America), Cup-corals, and a small *Leptæna*, for several yards along the coast.
4. Yellow and brown shales, hard and soft beds, for about 40 yards, containing:—*Orthocerata*, small Goniatites, Cup-corals, one species very similar to *Cyathophyllum Decheni* of the Eifel, *C. cæspitosum*, &c.; of Trilobites, two or three species of *Phacops*, straight and coiled, *P.* (*Dalmania*) *punctata*, very characteristic, and *P. bufo*, &c.; of Brachiopoda, *Leptæna*, *Orthis*, *Rhynchonella*, *Atrypa*, and one Spirifer, all very minute species; small Encrinite stems, and minute fragments of bone or spicula on yellowish shale, and a *Calceola*?
5. Green claystone, and purple and green shales with beds of grey fossiliferous limestone, for about 50 yards; full dip S. 30° W. at from 60° to 70°.
6. Yellow claystone with nodules of grey fossiliferous limestone for about 13 yards, containing a Coral like *Favosites Gothlandica*.
7. Purple and white shales with bands of limestone for about 33 yards, fossiliferous in the purple shales, and containing:—Cup-corals, Brachiopoda (*Leptæna*, *Spirifera*, and *Orbicula*); and small Goniatites with markings very similar to *G. Marcellensis* of the Hamilton beds, America; of Trilobites, *Phacops bufo* &c.; and a small "bone" of a fish. The dip is S. 45° W. at 30°.
8. Grey, purple, and satiny yellow shales, with beds of grey limestone for a distance of about 200 yards, very much disturbed and contorted, and lying nearly perpendicular. Line of strike S. 75° E.
9. A bed of trachytic stone, light-brown colour.
10. Brown claystone with small nodules of light-brown limestone, hard and thick-bedded (very similar to that observed at the S.W. promontory), along with thin beds of grey limestone, for about 50 yards. Full dip N. 75° E.; well shown in cliffs, and lying nearly perpendicular.
11. Soft claystone mixed in part with thin grey grit-stone, for 30 yards.
12. Grey shale with limestone nodules for 13 yards; full dip N. 20° E.

13. Greyish shale or claystone, stratified, for 15 yards, and dipping about
      N. 65° E.
14. Soft yellowish stone with ironstone for 13 yards, much contorted.   This
      stone has no appearance of stratification, and does not apparently belong
      to the same age of rocks as the adjoining shales.
15. Trachytic rocks, already mentioned above.

Having now described the whole of the Primary strata of the island, it will be readily seen that, setting aside the variations and contortions of the beds in the vicinity of the trachytic rocks, a distinct ascending order of Primary strata can be traced from the north-eastern to the south-western portion of the island.

The fossiliferous argillaceous strata of the series form but a thin imperfect band as compared with the great mass of quartz rocks, of which almost the entire body of the San George Mountain is composed; but they are sufficient to fix their age as true Devonian strata.   I shall reserve any further remarks as to their exact position in the Devonian series until the description of the adjoining island of Andirovitho has been given, where much additional evidence has been discovered.

The question of the origin of the quartzose rocks met with on the Bosphorus and in the adjoining islands is clearly solved on the south-east coast of Prinkipo; for we find those rocks interstratified there with other beds of a different character; whilst on the very top of the San George there is a thick bed of conglomeratic quartz composed of large rounded boulders, which is evidently the remains of an ancient sea-beach.   The sandstones of the series have, in fact, been metamorphosed into a solid quartz rock.

And could not the phenomenon of the ironstone at the junction of these rocks and the trachytes be accounted for also by the total absence of this substance in the quartz, when we know that sandstones generally contain a considerable proportion of iron?   Could it not have been melted out of the adjoining sandstones by intense heat at the time of the eruption of the trachytes, and run off into these rocks; just as iron is extracted from the ore by smelting in modern times?

3. *Island of Andirovitho.*—This island is situated on the eastern side of Prinkipo, and measures about 1100 yards in length by 600 yards in extreme breadth.   With the exception of a small spot of cultivated land at the extreme end, the island is barren and rocky, and its greatest height above the sea-level does not exceed 60 or 70 feet.

The strata are composed entirely of sedimentary rocks, and, from an inspection of their enclosed fossils, are of Devonian age; and they are exceedingly interesting as exhibiting an entirely new series compared with that of the Bosphorus, the fossils also being found here in a much more perfect state of preservation.   Limestone is the prevailing stone of the island; and some of the beds are of great thickness and purity.   Here a profusion of corals is to be seen, and in so much more abundance than anywhere on the Bosphorus or the adjoining mainland, that these strata may with propriety be

designated the " Coral-reefs" of the Devonian system of Turkey. Some beds, in particular, seem to be entirely composed of a mass of ancient coral. The full dip of the strata is nearly south-west, at an angle varying from 35° to 70°; and a very regular ascending series can be traced from the northern to the southern extremity of the island.

Beginning at the northern end, the strata are composed of yellow, brown, purple, and grey (the latter predominating) hard shales, with grey and brown bands of impure limestone, and dipping regularly S. 40° W. to S. 55° W., at an angle of from 35° to 40°. These beds are rich in fossils of various kinds. Here are Corals of the genera *Heliolites*—*H. porosa* (*Porites pyriformis*) &c.; of *Favosites*, *F. polymorpha*, *F. Gothlandica*, *F. Goldfussi*, &c.; of Cup-corals, *Cyathophyllum cæspitosum*, *C. vesiculosum*, &c., and many other beautiful varieties similar to *Zaphrentis*, *Strephodes*, *Omphyma*, *Strombodes*, &c. To these may be added many forms of the genera *Fenestella*, *Syringopora*, and *Aulopora serpens*, the two latter very characteristic. Highly characteristic, also, of these beds are the Brachiopod shells *Atrypa reticularis* and *A. squamosa*, or *A. aspera*, and the univalve *Euomphalus*, both large and small species, besides several other Brachiopods in abundance, such as *Leptæna*, *Strophomena*, *Atrypa*, *Spirifera*, *Orthis* &c.; also the Pteropod shell *Tentaculites annulatus*, and stems of large Encrinites. Trilobites are rare, one of the genus *Phacops*, and an undescribed form, having alone been met with in those beds; neither have I been more successful in detecting them in any other strata of the island. One thin band of impure grey limestone near the north end is composed almost entirely of large Spirifers, of species undescribed, one very similar to *S. concentrica* of the Eifel beds in Germany; while another band of purple shale, a little further to the south, is laden with minute Brachiopoda (*Orthidæ* &c.), with large *Euomphali*, Corals, and stems of small Encrinites.

The next series of beds is composed of hard grey and purple shales, much contorted, and dipping S. 5° E., from 65° to 70°, in which I could not discover any fossils. These beds are apparently the same as those seen on the north-east side of Prinkipo, and in which stems of Encrinites only could be traced.

Proceeding south along the eastern side of the island, we now arrive at thick beds of hard dark-grey subcrystalline limestone, dipping S. 27° W., from 30° to 35°, stretching along the coast for a distance of about 150 yards, and replete with Corals of the genera *Favosites* (*F. Gothlandica*), *Heliolites* (*H. porosa*), and another genus undescribed. Some of the beds are composed of a mass of Coral, while other fossils are almost entirely wanting throughout their whole extent.

Beyond them come in yellow and purple shales, and thick beds of dark-grey limestone, contorted, dipping at their southern end S. 30° W., at 75°, and containing many Corals and Brachiopoda. In an old limestone-quarry near their termination, a trap dyke has been exposed to view, of a light-green colour, and about 10 feet wide, which crossed the island in a W.N.W. direction.

Lastly follow hard dark-grey calcareous shales, and beds of lime-stone (same colour), much contorted, and dipping about S. 60° W., from 55° to 60°, the whole almost destitute of life, excepting a few imperfect *Orthocerata*, and Corals of the genus *Cyathophyllum*. These beds form the entire southern portion of the island. It is not necessary to continue this description around the western side of the island, as the strata are similar to those of the eastern side.

In comparing now the strata of this island with those of Prinkipo, it will be seen that if we can prove the grey and purple shales of the north-east coast of Prinkipo to be the same as those on Andiro-vitho, of which there can be little doubt, we shall have found an additional link to the series of Primary strata of Prinkipo, which at present is replaced by trachytic rocks,—and with the additional interest that they exhibit a mass of evidence on the age of those rocks not to be found elsewhere in the adjoining islands, nor yet on the mainland, and without which the fossil evidence of the south-west side of Prinkipo would be but fragmentary. As the case stands, however, the mass of Coral evidence in these Andirovitho beds, accompanied by that of other characteristic fossils, such as *Atrypa reticularis* and *A. squamosa* and many *Euomphali* &c., marks an epoch distinct from that of the Lower Devonian shales of the Bos-phorus, with their broad-winged Spirifers and the wonderful Coral *Pleurodictyum problematicum*, and might with propriety be con-sidered a "middle series," there being sufficient evidence to warrant this, although several typical genera of similar rocks in England and Germany have not yet been found, such as *Stringocephalus* and *Megalodon*. Be that as it may, we have a decided leaning to the Upper Devonian in the fossiliferous shales and impure limestones of the next series in ascending order, on the south-west side of Prin-kipo, where Goniatites are in sufficient numbers to become charac-teristic; while Spirifers and other Brachiopoda are scarcely repre-sented, and only by small forms. The *Orthocerata* are also more plentiful, and of larger forms than any hitherto found. Trilobites, too, are far from rare in these beds, but restricted, as in England, to the genus *Phacops*, of which three species at least have been described.

In conclusion, I would refer here to the finding of a small bone in the beds (No. 7) on the south-west side of Prinkipo; and from its appearance and section of fracture I should say that it is a bone of a fish; and if so, it is the first evidence of fish discovered, to my know-ledge, in the Devonian strata of Turkey.

4. *Island of Chalki.*—This picturesque island lies to the north-west of Prinkipo, and derives its name from the Greek work "chalko," copper—tradition affirming that the metal abounds in the island, and was largely worked in ancient times. This idea appears to be based on the fact that large quantities of the supposed scoria, from the smelting of the ore, are still lying strewed along the beach of the southern and eastern sides of the island; whereas the real facts of the case seem to be, that the supposed scoria is simply the ironstone washed from the opposite trachytic cliffs of Prinkipo, yet exceedingly similar in appearance to the cinder derived from copper-smelting.

The rocks of the island may be divided into—(1) Primary sedimentary strata, and (2) Trachytic rocks.

(1.) The sedimentary rocks are chiefly confined to a thin band of shales and sandstone around the northern coast of the island, much metamorphosed by the action of the adjoining igneous rocks, and interstratified in places with them. Fossil remains are extremely rare in these beds; an impression of what would seem to be a Goniatite, in brown shale, and a doubtful one of the stem of a plant, are all that can be recorded: they are, however, sufficient to place these rocks with the Devonian strata of Prinkipo, and are probably of the same age in the series.

(2.) These strata are similar to the soft white feldspathic rocks in the opposite coast of Prinkipo, and need, therefore, little further description here. The stone in general is less siliceous in its nature, and approaches nearer to a pure kaolin than that of Prinkipo; the joints are also less impregnated with iron; and I have not been able to detect any great masses of iron-ore throughout the whole of the island.

In concluding the description of Chalki, I must not omit to remark that at the extreme end of the beautiful little bay of Tchemliman the trachytes are seen to be impregnated with green carbonate of copper in minute veins, similar to those near Morton's Mill on Prinkipo.

5. *Island of Petala or Peta.*—There is nothing of importance, geologically speaking, to notice respecting this island; the strata are white trachytes, similar to those of Chalki.

6. *Island of Antigoni.*—Antigoni may be said to be almost entirely of volcanic origin, and is composed principally of soft white feldspathic trachytes, coloured red in parts by the presence of iron. There occur, however, on the north-eastern coast of the island, variegated white and purple sandstones, and grey quartzose rocks, which have every appearance of being stratified, and may probably at some future time be classified with the sedimentary Devonian rocks of the Island of Proti, which I shall now proceed to describe.

7. *Island of Proti.*—The physical features of Proti are sterile and uninviting; and in consequence this island is the least frequented by the pleasure-seekers of the capital.

The geological features, on the contrary, are exceedingly interesting, exhibiting a series of strata entirely different from those of any other of these islands (if we except a small portion of Antigoni, just described), and forming another link by which to join together the several detached portions of Devonian strata, of which the Princes Islands are the remains. Here are to be seen, for the first time in all my examinations (as well here as on the mainland), to any extent, red sandstones, as if to prove the relationship by colour, if not by animal life, of the Turkish Devonian rocks to those of Hugh Miller's Old Red Sandstone series of Scotland.

The strata of Proti are entirely of sedimentary origin, arranged in a basin- or troughlike shape, and composed of sandstones, highly micaceous in part, of colours red, purple, white, and grey, associated

with thick beds of white tabular quartz and quartzose sandstones, coloured red in part, which are evidently altered sandstones; and their relation to the adjoining rocks is well exemplified in the cliffs which form the south-western point of the island, where the quartz rocks are seen distinctly interstratified between beds of light-grey and purple sandstone.

Beginning at the extreme south-eastern coast of the island, and going west a distance of about 150 yards, the strata are seen in the cliffs dipping N. 70° W., at an angle of 30°, in the following ascending order:—

1. White micaceous granular sandstone.
2. White and light-green softish micaceous sandstone, with bands of purple highly micaceous sandstone.
3. Purple highly micaceous sandstones, moderately hard, and dipping regularly. Impressions of Fucoids.

Going westward, these sandstones disappear under covered ground, and are no more seen until arriving at the north-western side of the island, when sandstones come in again under the quartz rocks which form the intermediate strata of the island, and, gradually rising from under them, form the whole coast-line of the northern side of the island, in the following descending order, going east. Immediately under the quartz rocks are:—

1. Purple and white sandstones.
2. Red highly micaceous soft sandstones, with bands of whitish micaceous sandstone, dipping S. 35° W., at 25°, forming cliffs fully 100 feet in height around the north-western side.
3. White and purple soft sandstones, dipping same as No. 2 beds, and forming cliffs about 100 feet in height.
4. White sandstones, forming the extreme north-eastern point of the island and a short distance round the eastern side.

In the remains of animal life the strata of this island are singularly bare, none having yet been discovered; and the same may be said of the vegetable forms of life, with the exception of two specimens of Fucoids, found in the purple sandstones of the southern side. I had hoped that the sandstones would afford the remains of fishes, but as yet I have not been successful in finding even the slightest trace of them.

8. *Island of Niandros.*—The strata are composed entirely of white quartz, the beds of which are distinctly seen to be stratified, and dipping from S. 75° W. to S. 55° W., at an angle of from 40° to 60°; and they are evidently a continuation, upwards, of the Devonian rocks of the Island of Prinkipo.

9. *Island of Plati.*—Geologically speaking, this island is a mass of white quartzose rocks, evidently altered sandstones, reaching to a height of 60 or 80 feet above the sea-level. The dip of the beds is very distinctly seen in an artificial cave, near the landing-place and on the north-west side of the island, varying from S. 10° W. to S. 30° W., at an angle of 20°. The strata may safely be reckoned as Devonian, and form, in all probability, the extreme verge of the series in a south-westerly direction.

The remaining island (Oxia) I did not visit.

10. *General observations.*—Throughout the whole examination of the Princes Islands I have been greatly struck with the regularity of the line of dip whenever local causes do not occur to affect it; it may be taken to vary from S. 45° W. to S. 75° W.; and this regularity is very marked in the quartz beds throughout, which have greatly served as a guide in arriving at this conclusion. I have also examined the coast of the mainland to the north-east of Prinkipo, and find the dip there, at the village of Khartal and eastward, from S. 65° W. at 35°, to S. 35° W. at 75° to 80°, for a distance of about a quarter of a mile; and then it suddenly reverses and dips north-east, and continues so as far as I went, or about two miles and a half along the beach towards the village of Pendik. The description of these beds will be reserved for a future memoir.

If we assume that the line of dip is about S. 45° W., then we must conclude that the "Red Sandstones" of Proti come in between the Island of Prinkipo and the mainland. But on the other hand, if we assume the full dip to be about S. 75° W., then the "Red Sandstones" would come in between Plati and Prinkipo, on the line of Antigoni, and would correspond with the white and purple sandstones of the latter island; and I am inclined to take this latter as the correct view of the case.

And if we measure a line from Plati or Oxia to the mainland, in the full rise of the strata we have a distance of about five to six miles, represented in all probability by a perpendicular thickness of about 18,000 to 20,000 feet of strata, which have been almost entirely swept away from the Devonian mainland in ages past, and are at present represented by the Princes Islands.

And here, in conclusion, it will not be out of place to remark that in the course of my many observations on the geology of the Bithynian peninsula, from many points, I have found the strata to be disposed in a basin-like form, the line of the Bosphorus forming the western lip of the basin, and the full rise of the strata gradually sweeping round to the north on the northern or Black-Sea side, and to the south on the southern or Sea-of-Marmora side, the centre of the basin appearing to be the high chain of mountains of Kaish Dugh, the Two Brothers, &c.; but this I do not yet know for certain; nor have I yet visited the eastern side of the Devonian strata, and therefore I cannot say if the basin-shape is preserved throughout. The disposition of the strata of the Princes Islands clearly corresponds with these observations.

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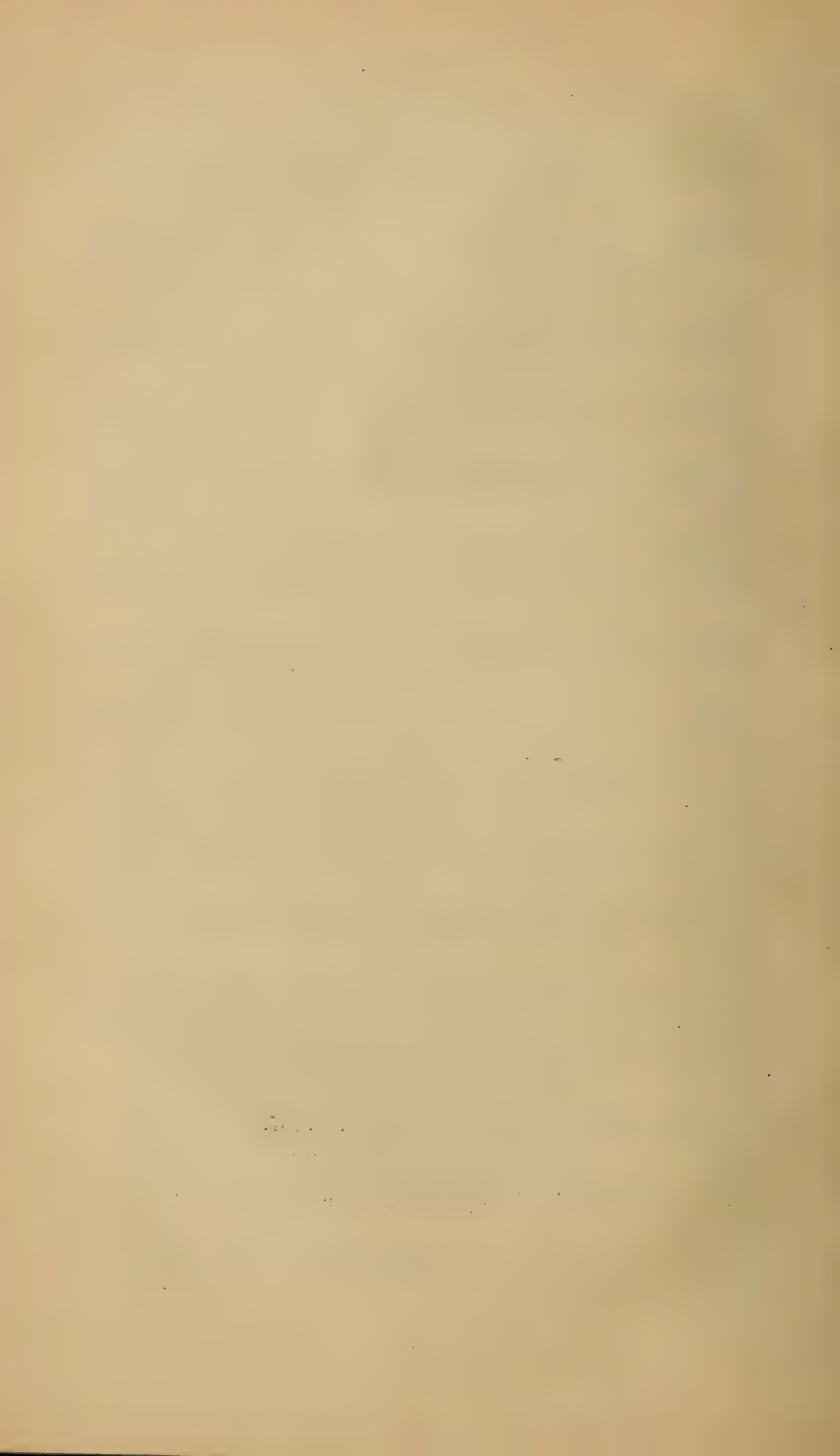
PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

DECEMBER 18, 1867.

T. Jones, Esq., 13 Dundas Terrace, Hampstead; Martin Crofton Morrison, Esq., late H.M. Consul in China; James Wood Mason, Esq., Queen's College, Oxford; Marriott Ogle Tarbotton, Esq., 103 Victoria Street, Westminster; and the Rev. Thomas Nicholson, M.A., Ph.D., 3 Craven Street, Strand, were elected Fellows.

The following communications were read :—

1. *On the* PARALLEL ROADS *of* GLEN ROY.
By Sir JOHN LUBBOCK, Bart., F.R.S., F.G.S., Pres. Ent. Soc.

DURING the course of last autumn I had an opportunity of visiting the celebrated Parallel Roads of Glen Roy, and, having been thereby led to study the various memoirs which have been written on this interesting subject, I have been brought to the conclusion that the explanation given originally by Macculloch, as to the manner in which the roads were produced, is not the correct one, although it has been adopted by almost every one who has subsequently discussed their origin.

I do not propose to reopen the discussion of the causes owing to which the valley was filled with water, but, taking for granted that these "roads" or "shelves" represent water-levels, to consider the manner in which they have been formed. This is indeed a minor point; but I think I need not apologize to the Society for the attempt

to obtain a clearer and more definite insight even into one of the lesser operations of nature.   I will therefore first describe the roads briefly, and only so far as is necessary for my purpose, doing so, moreover, almost entirely in the words of Macculloch, Darwin, Lyell, &c.; secondly, I will give the explanations of earlier writers; and lastly I will point out what I believe to have been the true *modus operandi*.

The parallel roads or shelves are three in number on each side of the valley; the corresponding ones on the opposite sides are exactly at the same level; and all are perfectly horizontal.   So regular, indeed, are they that they irresistibly remind one of lines ruled in a copybook, however incongruous and farfetched such an idea may be.

The sides of Glen Roy are steep and have an equable slope. "The natural rock," says Macculloch, "is but rarely seen " * ; and Mr. Darwin observes that " the shelves entirely disappear where crossing any part of the mountains in which the base-rock is exposed" †. The loose materials of which the slope is formed " have," in the words of Macculloch, " evidently descended from the hill above." That this is their origin, and that they are not transported materials, is plain, since they are not rounded, and since they exactly resemble the natural rock, which is of a remarkable character, consisting of mica slate traversed by numerous veins of red granite—a rock which is limited to the upper part of the glen, and is not found in the neighbouring hills ‡.

" The parallel roads, shelves, or lines, as they have been indifferently called, are most plainly developed in Glen Roy.   They extend in lines, absolutely horizontal, along the steep grassy sides of the mountains, which are covered with a mantle, unusually thick, of slightly argillaceous alluvium.   They consist of narrow terraces, which, however, are never quite flat, like artificial ones, but gently slope towards the valley, with an average breadth of about sixty feet " § .

" In general," says Macculloch, " sixty feet may be assumed as an average breadth ; by far the greatest portion of all the lines will be found to conform to this measurement " ‖. .   .   .   .   " The extreme breadth may safely be taken at seventy feet, or a little more ; and their most general one lies between that and fifty.   As in no instance that I have remarked do they exceed the former, so they very rarely indeed fall short of the latter dimension " ¶.   " On the slope of a brown hill in Glen Fintec" (he says elsewhere)** " they are particularly worthy of remark on account of their continuity, preservation, and the almost absolute equality of their dimensions, not only through the course of each individual line, but respectively to each other."   This uniformity of width is a remarkable feature of the shelves, which has struck most observers, but of

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* Geol. Trans., Ser. 1, vol. iv. p. 320.   † Phil. Trans. 1839, p. 40.
‡ Macculloch, *l. c.* p. 320.   § Darwin, *l. c.* p. 39.
‖ *Loc. cit.* p. 322.   ¶ *L. c.* p. 337.
** *L. c.* p. 328.

which no explanation has yet been afforded. In those places, how-
ever, where the roads are narrower than usual, their inclination is
also more considerable *.

The shelves " contain fewer well-rounded pebbles at the greater
heights than would be expected on any theory of their origin " †.

For several miles " these three lines pass along both sides of
Glenroy with scarcely any interruption " ‡.

" The lines are not grooves " §; they resemble sections of parallel
layers applied in succession to the face of the hill " ‖. This is a
point of great importance. " In only one instance," says Maccul-
loch, " is there a slope resembling a superior talus, ...
while in no instance did I perceive the marks of an inferior one."
The true relation of the shelves to the hill is shown in the accom-
panying diagram, which was given by Dr. Macculloch, and has

Fig. 1.—*Section of the Parallel Roads of Glen Roy, after
Macculloch.*

a b, present slope.
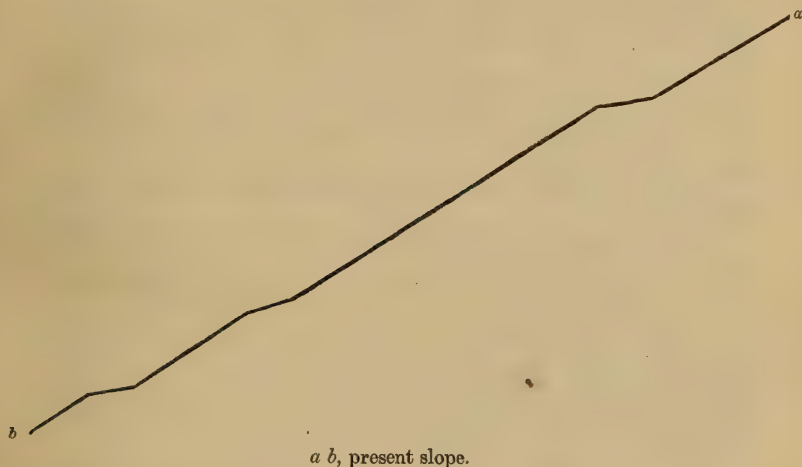
been accepted and copied by Mr. Darwin, Mr. Chambers, and Sir C.
Lyell. It will be observed that the general slope of the hill is the
same above and below the road. In fact there are but two slopes, one
that of the hill, the other that of the roads. Both vary somewhat
in different parts of the glen, preserving, however, about the same
ratio to one another.

Finally, the lines " entirely disappear when crossing any part
which is gently inclined " ¶.

* Macculloch, p. 320.   † Darwin, p. 41.
‡ Chambers, Ancient Sea Margins, p. 97; Darwin, p. 75.
§ Jamieson, Quart. Journ. Geol. Soc. vol. xix. p. 233.
‖ Macculloch, p. 337.   ¶ Darwin, p. 40.
                                                      H 2

I am prepared to accept the substantial accuracy of the above woodcut, with one important alteration. It is sufficiently obvious that if " a " is the present summit of the hill, the old one must have been somewhat higher, say at a', and the original slope consequently steeper than $a\ b$.

As regards the facts, then, we have a substantial agreement; and they may be summed up as follows:—

1st. The side of the hill is covered with rubbish derived from the weathering of the rocks.

2nd. The roads are not excavations in, nor embankments on, the side of the hill, but, in the words of Macculloch, resemble stairs, or sections of parallel layers applied in succession to the face of the hill.

3rd. The horizontal roads do not appear when the solid rock appears, nor when the slope is exceptionally flat.

4th. Macculloch only saw one case in which there was a superior talus, and never found any trace of an inferior one.

5th. The stones on the road are very little rounded.

6th. The roads are quite continuous, except under the circumstances named above, or where a rivulet runs down the side of the glen.

7th. The roads slope towards the valley.

8th. The roads are very equal in size. Not only is this the case with each road during its whole course, but it is also true of them as regards one another.

9th. When, however, they are narrower they are also steeper than usual.

The true explanation of the origin of the roads must be consistent with all these conditions.

I now proceed to consider the various explanations which have been suggested.

It is not, indeed, necessary to consider the theory which regarded them as literally roads made of old by Fingal and his brother heroes—nor the more prosaic but scarcely less preposterous one, that they were made for hunting-purposes by the early kings of Scotland.

Taking the principal authors who have written on the subject in chronological order, we commence with Dr. Macculloch, who thus explains how in his opinion the " roads " were formed.

" The water," he says, " checks the constant and gradual descent of the alluvia of the hills. The descending matters thus losing a large portion of their weight by immersion in the water, and in winter often rendered still more buoyant by being entangled in ice, are thrown back against the face of the hill by the incessant action of the superficial waves, and are thus evenly spread against its side." *

Sir T. Lauder Dick† gives a diagram of a lake with precipitous banks, in which he supposes that the water would excavate a hollow. If, however, the materials were sufficiently solid to stand at so

* *Loc. cit.* p. 371.   † Edinb. Roy. Soc. Trans. vol. ix.

high an angle as that indicated by him, I doubt whether the still waters of an inland lake would have sufficient power to eat them away. Moreover the case is not one of mere erosion.

Mr. Darwin expresses himself as follows :—

The shelves "seem to have been formed, as suggested by Macculloch, by the check given to the downward descent of ordinary detritus, and that transported by torrents, at the level of the ancient waters" (p. 41). Again—

"The fringe of rudely stratified alluvium, the origin of which we are considering, resembles, both in structure and composition, such beds of detritus as would have accumulated on the shores of a lake had one existed in these valleys" (p. 51). And once more—

"The two regular shelves are, perhaps, more plainly marked here than in any other part of the whole glen ; and it would appear probable that this is owing to that portion having been exposed to a longer space of open water, by which means the ancient waves acquired a greater than ordinary power in heaping up detritus " (p. 62).

Mr. Milne-Holme does not enter much into this part of the subject. He says, however, "In a lake which has no movements of water either vertical or lateral, the detritus deposited on the sides of a valley occupied by it will be scarcely if at all removed, and will thus form projecting buttresses nearly flat on their upper surfaces, and presenting steep escarpments towards the lake "[*].

Prof. Rogers [†] regards the roads as "nearly level, wide, deep grooves in the easily eroded boulder-drift or diluvium which, to a greater or less thickness, everywhere clothes the sides of these mountains ;" and he supposes these grooves to have been cut by a great inundation coming from the Atlantic.

Mr. Robert Chambers [‡] also considers the roads to be "lines of indentation " in the otherwise uniform slope of the hill.

Mr. Jamieson follows Macculloch. The terraces are formed, according to him, "by the check which the water of the old lake gave to the descent of the *débris* washed into it by the rains and streams, as Macculloch long ago pointed out. They are, if I might use the expression, the continuous deltas formed by the rains and other atmospheric agents "[§].

Finally, Sir C. Lyell expresses himself as follows :—" The parallel shelves have not been caused by denudation, but by the deposition of detritus precisely similar to that which is dispersed in smaller quantities over the declivities of the hills above "[||].

"It is well known that wherever a lake or marine fiord exists, surrounded by steep mountains subject to disintegration by frost or the action of torrents, some loose matter is washed down annually, especially during the melting of snow, and a check is given to the descent of this detritus at the point where it reaches the waters of

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[*] Edinburgh Royal Soc. Trans. vol. xvi. 1847.
[†] Lecture at the Royal Institution, March 22, 1861.
[‡] Ancient Sea Margins.   [§] Quart. Journ. Geol. Soc. vol. xix. p. 238.
[||] Antiquity of Man, p. 253.

the lake. The waves then spread out the materials along the shore, and throw some of them upon the beach, their dispersing power being aided by the ice, which often adheres to pebbles during the winter, and gives buoyancy to them " *.

Influenced by this idea of matter being "thrown up" by the waves, he accounts for the intermediate shelf on Tombhran by the fact that " it occurs where there was the longest space of open water, and where the waves may have acquired a more than ordinary power to heap up detritus ".

It is fair to remember that all these eminent writers were principally occupied in considering how the water filled the valley. If their attention had been mainly directed to the manner in which the shelves had been formed, I cannot but think that they would have arrived at a different explanation.

Fig. 2.—*Section of the Roads* Fig. 3.—*Section of the Roads ac-*
  according to the theory of   *cording to Sir T. Lauder*
  Macculloch.   *Dick's theory.*
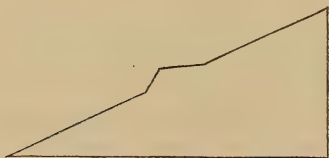
If, for instance, the theory advocated by Sir T. L. Dick and Prof. Rogers were sufficient to explain the whole matter, the section presented by the side of the hill ought to have shown an excavation, as in fig. 3. On the other hand, if the theory first proposed by Dr. Macculloch and adopted by Mr. Darwin, Mr. Milne, Mr. Jamieson, and Sir Charles Lyell were the correct one, the section would be a projection, as in fig. 2. The true outline, however, as admitted by almost all observers, is that represented in fig. 1; nowhere, as we have already seen, does it resemble that of fig. 2. Moreover, if the roads were owing to the heaping up of loose detritus "washed down annually, and especially during the melting of snow," the shelves ought to be broadest where rivulets come down the sides of the hills, whereas, on the contrary, these streamlets have, as is well known, actually produced the opposite effect, and cut back the hillside.

Not only does this theory require a very different relation between the hill and the roads, but it leaves unexplained the very even width of the roads themselves.

As loose matter would be, and in fact has been, washed down much more abundantly in some places than in others, the roads must, on any such hypothesis, vary greatly in width. This, how-

* *Op. cit.* p. 255.

ever, as we have seen, is not the case; but, on the contrary, the very even breadth of the roads is one of their most remarkable peculiarities.

Much of the confusion has, I think, arisen from the notion that the roads were "continuous deltas." This idea was evidently uppermost in the minds of Dr. Macculloch, Mr. Darwin, and Sir C. Lyell, when they spoke of the "check given to the downward descent of ordinary detritus." But in the case of a delta the check is not given directly to the solid matter, but to the water carrying that matter. The power of running water to carry solid matter with it varies with its velocity; and when the current is stopped, the translation of this matter of course ceases also. Solid matter, on the contrary, rolling by its own momentum down a slope, moves under very different conditions, and would not be arrested by water, but (unless indeed, lighter than the water) would continue to descend until it came to a slope on which it could stand.

We see that this is the case in Glen Roy itself, and that the shelves have not been formed where streams come down the slope. Not only does the matter they carry down go on to the bottom of the Glen, but the streams cut back the side of the hill, and the shelves are wanting exactly where they ought, on Dr. Macculloch's theory, to be most strongly developed.

No doubt there *are* cases in which terraces have been thrown up by waves on the side of a hill. In such cases, however, it seems to me that we should have a section somewhat like that shown below (fig. 4). This, however, differs from the Glen-Roy section in two important particulars. In the first place, the slope of the shelves is

Fig. 4.—*Section illustrating the form of Sea-beaches.*

away from, and not towards, the water; and, secondly, there must be a flat (*a*) within reach of the waves, and from which they may obtain the materials to throw up. Moreover, in such a case the pebbles &c. forming the shelves must be more or less rounded.

I will now proceed to state my own idea as to the manner in which the roads have been formed.

In order to understand the matter thoroughly we must go back to the far-distant time when the valley first acquired its present depth and width. It is evident that the sides were then steeper and more rugged, because the solid rock, as we have already seen, seldom comes to the present surface, but is hidden by a thick covering of what has often been called "alluvium," or rather "detritus."

In order to realize what would take place under these circumstances we have but to remember what we have most of us seen in many a Swiss valley. On each side rise steep cliffs, at the foot of which is a larger or smaller "talus" of fragments detached from above. The rock gradually weathers, and the fragments falling down accumulate at the bottom, forming a heap, with its back against the cliff and a slope towards the valley. The angle of this slope varies according to the nature of the material, but under the same circumstances is constant.

This "talus" reaches to a greater or less height up the rock, and it is evident that the time must eventually come when, from the degradation of the cliff and the accumulation of the talus, the valley will at length be bounded by equable slopes.

The angle of these slopes will depend on the nature of the materials.

Mr. Edwin Clark has kindly given me the following list, taken from Rankine's 'Manual':—

Dry sand, clay, and mixed earth........	from	37° to 21°.
Wet clay	„	17° „ 14°.
Damp clay...................................	„	45°.
Shingle and gravel	„	48° to 35°.
Peat	„	45° „ 14°.

Molesworth gives the following:—

Gravel .... (average)		40°.
Dry sand...........	„	38°.
Sand	„	22°.
Vegetable earth ...	„	28°.
Compact earth ...	„	50°.
Shingle	„	39°.
Rubble	„	45°.
Clay, well drained	„	45°.
Clay, wet	„	16°.

There are, then, great differences between different substances, and even between the same substance under different conditions. It appears evident, however, that in still water the angle would be the same as in air.

As this is a point of much importance, and as I have found a very general impression that the angle of repose in water would be different from that in air, I have put myself in communication with Prof. W. J. Macquorn Rankine, and subjoin his reply:—

"*Angle of repose.*

"59 St. Vincent Street, Glasgow.

"MY DEAR SIR JOHN,—So far as my observation and experience have gone, the angle of repose, or natural slope, of coarse detritus consisting of fragments not capable of being softened or lubricated by water is the same in still water as in air.

"The obvious explanation of this fact is, that the ratio of friction to pressure, upon which the angle of repose depends, is not altered

by the presence of a fluid which neither softens nor lubricates the solid fragments.

" The *absolute* pressure and friction are, of course, diminished in water through buoyancy; and therefore the solid fragments are more easily displaced by any disturbing force in water than they are in air: but in the absence of disturbing force their positions of equilibrium are the same in both fluids.

" I may state that I have seen even *sand* stand under *perfectly still* water at as steep a slope as in air.   The grains were rough and angular; had they been rounded and smooth, the water would have acted as a lubricant, and diminished the angle of repose.

" I may remark that there is only one perfectly satisfactory way of settling such questions as this; and that is, by experiment.

<div style="text-align:center">" I am, my dear Sir John,
" Yours very faithfully,
" W. J. Macquorn Rankine."</div>

Now in the case of Glen Roy it is probable, from the occasional appearance of the solid rock, that the sides were never very perpendicular.   However this may be, all observers are agreed that they are now covered with a thick layer of angular detritus, and that the solid rock rarely comes to the surface.

It seems to me evident that the detritus stands at its angle of repose, though this cannot be proved by calculation.   The slope of the sides of the valley appears, however, to be very nearly what we should expect from the Table given above.   Moreover it is, I think, sufficiently obvious, from the circumstances of the case, that the present slope is very nearly, if not exactly, that of repose.   For if not, it must be either at a greater or a less inclination.   But loose matter cannot stand at a greater angle than that of repose; and the sides of Glen Roy have evidently suffered little change since the Glacial period.   They cannot, therefore, be at a greater angle than that of repose.   Neither can they be at a less inclination; for they are formed of detritus which has come down from above by weathering, while if the angle had been less, the detritus could not have come down.

Again, we know that when the lake stood at the level of the two upper terraces, several streams ran into it; now, if the inclination of the hill had been less than the angle of repose, the matter brought down by these streams would have rested where they entered the lake, and formed deltas.   This, however, as Mr. Jamieson remarks, and as his map shows, has not been the case.   The angle of repose of any given substance can, as I have already observed, only be determined by experiment; and it has been suggested to me that I should endeavour in this way to determine whether the sides of Glen Roy do stand at the angle of repose.   It would, however, be difficult, if not impossible, to reproduce the exact conditions; nor, indeed, is it necessary, since nature has herself tried the experiment for us.   It therefore seems to me evident that the sides of Glen Roy do stand at the angle of repose; and it is also clear that they must

have done so before the valley was filled with water, because seve-
ral of the lateral streams had cut back the slopes to a considerable
depth before the formation of the lake, so that the " roads" wind
into the recesses thus produced.

Given, then, a valley with sides sloping at the angle at which the
matter of which they are composed will stand, what will happen
if the lower end is dammed up, and a lake formed?

The deep still water below the surface would effect no change; but
although in a narrow mountain-locked valley no very great dis-
turbance of the water would take place, still the waves would have
a certain amount of rolling-power. Now, suppose a stone at the
edge of the lake moved by the water a little either to one side or
the other; being on a slope, of course it would have a tendency
downwards; and of the stones once moved, a large proportion would,
when once disturbed, roll down at once to the bottom of the valley.
Any one may try this on a small scale, as I have done, and satisfy
himself by experiment that this would be the result.

It is evident that in this way two fresh angles of slope would be
produced—one immediately below the water at a less inclination
than before, and the other above the water at a steeper one. But
the original angle was that at which the material would stand, and
the steeper slope above the water would therefore immediately begin
to crumble back until it reacquired the slope of equilibrium, which,
as the matter has had time to settle and become somewhat consoli-
dated, would naturally be slightly steeper than before*. As soon as
the slope of repose was reacquired, the crumbling would be checked,
the two slopes would have acquired a condition of repose; and even
if there were a steeper part above, supplying fresh matter, the impe-
tus of fall would carry it in most cases over the road, which there-
fore would not be obliterated.

A block is now shown which fell a year or two ago, and which,
far from stopping on the roads, has been driven by its impetus part
of the way up the opposite hill.

Mr. Darwin remarks, as we have seen, that the shelves " contain
fewer well-rounded pebbles at the greater heights than would be
expected on any theory of their origin." If, however, my idea is
correct, the stones remaining on the shelves are those which have
not been much moved by the water, and would therefore naturally
not show much trace of wear.

No suggestion, I think, has yet been made to account for the
uniformity in the breadth of the roads. This also follows, however,
as a consequence of my theory; for as the angle of the roads neces-
sarily varies within narrow limits, and the depth to which the water
is disturbed in different parts of the valley does not greatly differ,
the breadth of the roads, which commence from the water-level and
reach down as far as the disturbed water reaches, cannot vary much.

It will be observed that, according to Macculloch, not only is each
road pretty uniform in breadth, but the three different roads are also

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* I think it probable that this process would be facilitated by the absence of
vegetation, owing to the extreme cold.

much alike. Now, if their breadth depended on the supply of matter from above, it would depend on the time during which each was being formed; or if the supply were not constant, then the variations in the time and in the rate of supply must have just counterbalanced one another; and either of these hypotheses is, it must be admitted, very improbable.   If, however, they have been formed as I have ventured to suggest, then this uniformity will also be accounted for, because the water would tend to give them a certain slope, reaching to the depth affected by waves; and when these conditions were fulfilled the hill-side would be in a state of equilibrium, and would remain with little further alteration until, on a sinking of the water, the formation of another shelf commenced.   In fact the lower level of the roads marks the lower edge of the disturbed water, just as their upper edge coincides with its upper edge.   We thus see why the three shelves are so similar in size, and also why their width is least when their inclination is greatest.

We can also now clearly see why the lines " entirely disappear when crossing any part which is greatly inclined;" and we obtain an additional argument in favour of the " lake- " as against the " sea- " theory.   The action of the waves is, of course, most considerable at the surface; and the disturbance gradually diminishes downwards, until we at length reach the undisturbed water.   So also the upper edge of the roads is well marked, but the lower side passes almost insensibly into the general slope of the hill.   On Sir C. Lyell's theory it seems to me that the reverse ought to have been the case.

Mr. Jamieson, full of his idea that the lines were " continuous deltas," was naturally " struck with the remarkable absence of deltas along the two upper lines."   " I do not think," he adds, " the shorter course of the rivulets sufficient to account for this."   Certainly not; the true explanation is, that the matter brought by rivulets during the period of the upper shelves naturally went to the bottom of the valley, and forms the base of the existing deltas. If the valley were to be again filled up to the level of the highest shelf, the deltas would not be formed at that level, but the matter brought down by the streams would continue to be deposited almost as at present.   Only after it had built itself up to the height of the higher shelf would the delta be formed at that level.

It seems to me, therefore, that Mr. Chambers was more near the truth than Dr. Macculloch, and that, if we realize to ourselves that the action of the waves tended not to cast up, but to throw down the materials which it moved, we simply and easily explain all the various phenomena presented by these remarkable roads.   It is hardly necessary to add that the same explanation is of very wide application.

2. *On the* GEOLOGICAL FEATURES *of the* NORTHERN *part of* FORMOSA, *and of the* ADJACENT ISLANDS. By CUTHBERT COLLINGWOOD, M.B., F.L.S.

(Communicated by the Assistant-Secretary.)

[Abridged.]

THE west coast of Formosa is generally very flat, consisting of low alluvial plains for the most part, the monotony being broken here and there by a hill, which forms an important landmark. Such is the coral hill known as Apes' Hill, 1110 feet, marking the entrance to the port of Takau-con, on the south-west coast; and such are the two prominent peaks of Kwang-yin and Tai-tun (1720 and 2800 feet respectively), between which is situated the harbour of Tamsuy, on the north-west coast. Both of these are treaty ports. Besides these, there is no conspicuous elevation immediately upon the west coast. This coast, in all its middle portions at least, has been placed, during the present visit, by Commander Bullock, of H.M.S. "Serpent," 12 miles further west than appears on the most recent charts, thus very materially narrowing the passage between it and the Pescadores, known as the Formosa Channel. The only place where the hills approach this coast is in lat. 24° 15', where there is some tableland which is denuded into picturesque valleys at right angles to the shore. It is well known, however, that a considerable range of mountains runs nearly through the island from north to south, of which Mount Morrison is the culminating point. These mountains approach the east side of this island, and for the greater portion of it render it harbourless and inhospitable, the steep sides of the mountains running sheer down into the sea.

At Tamsuy, in the north-east of the island, the right bank of the river upon which the town stands rises to the height of about 100 feet or upwards, in an undulating manner, and is entirely composed of alluvial clay, containing a vast number of boulders of stone. These boulders are of the most various sizes, from such as could easily be lifted by the hand to large blocks of 20 feet in circumference. They are also of very varied forms, some being round and smooth, and evidently more or less rolled, while others are quite angular, and have little or no appearance of having been waterworn. I examined many of these blocks to see if I could discover any traces of striation which could be attributed to glacial action; but although I met with suspicious markings, I could not satisfy myself that they were due to the action of ice. Moreover there is no marked difference in the various boulders as to lithological character; but to all appearance they were all, with little variety, of the ordinary greenstone, though I am not in a position to say whence they are derived. Their presence and character, however, appeared to me at least remarkable, and worthy of further investigation.

Higher up the river, which in the main flows from east to west, the hills rise on the north side from an alluvial plain, and consist in their lower portion of a calcareous grit, which crops out from the grassy slopes in great angular blocks, having an inclination of 15° to

the north-east. Amongst these rocks are signs of volcanic action, in the form of jets of steam containing large quantities of sulphur, as described in another paper*. It is said that similar sulphur-springs are to be met with to the north of this point, among the hills and at Takau-con, in the south. I observed, close to the water's edge, beside a lagoon near the harbour, a spring of water strongly impregnated with sulphur, and which taints the air of the vicinity with a strong odour of sulphuretted hydrogen.

On the opposite (north-east) side of the island, sandstone prevails ; and the whole surroundings of Kelung are of that rock, which extends from Masou Peninsula, north of Kelung, to Petou promontory, on the south and east. The section of the coast between these points exhibits inclined beds of red sandstone, with an average dip of 16° or 17° S.E., the weather-worn outcrops producing an undulating country. The hills at the back of the town of Kelung are also of the same formation, and have a similar dip and strike ; but at the extreme eastern (or rather south-east) point of the line of section exposed (viz. Petou promontory), the sandstone beds become suddenly curved round from the *inclined* to a nearly *horizontal* position.

The harbour of Kelung is a spacious excavation or indentation of these sandstone strata, the entrance being blocked by a low flat sandstone island, 10 feet high, called Bush Island, on the south side. Between this and the southern mainland, is a larger island, called Palm Island, which was evidently made so by gradual wearing away by the sea.

The harbour of Kelung presents many remarkable and interesting features. The town, situated at the extreme end of it, and fully a mile from Bush Island, lies upon a level plain, which gradually narrows among the hills behind ; and these hills are conspicuously stratified with the same character and direction as those on the coast.

On the further side of this range is a small stream, which flows in one direction downward to Kelung, and in the opposite direction becomes the Tumsuy river, which crosses the island to the west, the same stream flowing on either side of a ridge or anticlinal axis in opposite directions.

The north side of the harbour is picturesquely indented, and covered more or less with trees ; but the south side, where the ascending strata are abruptly broken off, presents a beautiful succession of rounded knolls, separated by narrow valleys or ravines. Several remarkable caverns exist on the north side.

The effects of aqueous action upon the sandstone rock are very conspicuous in some parts of Kelung Harbour. Near one of the caves, and immediately upon the verge of high water, is a tall isolated sandstone rock, having the appearance of an old ruined castle, appropriately named Ruin Rock. The harder layers of sandstone having defied the effects of the weather, and of the spray which is dashed up during the north-east monsoon, to which the harbour is exposed, the softer portions have been more or less excavated, leaving a mimic resemblance of the ruined chambers of a building. But the most curious and

* Quart. Journ. Geol. Soc. vol. xxiii. p. 382.

extensive effects of the direct action of the sea are at the entrance of the harbour on either side. That on the south side (which I visited) is the more curious, because the effects are on a larger scale. Crossing over the narrow sandstone platform between Palm Island and the mainland, which is covered at high water, I found myself in an extraordinary spot, where the soft sandstone rock had been worn away by the force of the waves into a variety of fantastic forms.

Immediately outside Kelung Harbour rises an isolated steep conical rock, Kelung Island, 580 feet above the level of the sea. From its peculiar form, and from the fact that between it and the mainland there is everywhere 30 to 35 fathoms water, I should imagine it was some harder rock. There are no trees upon Kelung Island, as there are on the sandstone shores of the harbour; and on its north side, about two cables' distance, rises a small isolated peak 100 feet high.

I must not, however, quit the subject of Kelung Harbour without expressing my opinion that the land is slowly rising. Evidences of this are to be found on both sides of the harbour. Blocks of worn and washed coral strew the beach on the north side, and lie about confusedly at high-water mark, in the neighbourhood of Ruin Rock. Similar washed coral blocks lie on the beach, and between tide-marks on the south side, namely on Palm Island. The sandstone platform between Palm Island and the mainland, which has every appearance of having been excavated by the sea (which has slowly forced a passage through), is now very little below high-water mark ; and *above* the sea-level the sandstone rock bears plain indications of having been marked and worn by the waves of the sea. Beyond the present limits of the harbour the level plain shows the sea to have once extended so far ; and the inner third of the harbour is so shallow as to be a mere mud-flat at low water.

The entrance to Sau-o Bay is protected (or jeopardized) by a reef (Sau-o Reef), which is evidently a great trap dyke running out nearly at right angles to the coast. It makes its appearance above water two-thirds of a mile from the north point of the harbour, and rises at once 70 feet above low water. It extends 600 yards further out, for the most part only just above water. Sau-o Bay is shut in by high hills, for the most part steep, and densely clothed with forest. The formation is that of a compact black slaty rock, having a conspicuous cleavage of varying direction, and being in some places perpendicular to the level of the sea. There is no sandstone here, though there is abundance of sand upon the beaches.

It may not be uninteresting, perhaps, if I put together a few remarks upon the general geological features of some islands lying around the northern end of Formosa, which are but seldom seen, and some of which have never yet been described. My opportunities of examining these islands were very limited, and I can only, therefore, pretend to give a fragmentary account of their geological structure ; still I think any authentic information of these remote spots may possess value and interest.

I will also include in this notice a few words concerning the Pescadores or Ponghou archipelago, situated between Formosa and China, and between the parallels of 23° and 24° N. This cluster consists of twenty-one inhabited islands, besides several uninhabited rocks; and the portion of the group which I had an opportunity of seeing included Round Island, Three Island, Table and Tablet Islands, Fisher Island and Ponghou (the two largest of the group), and Observation Island. All these are of volcanic origin and formed of basalt. The characteristic features of basaltic formation were best observed in Table and Tablet Islands, the general aspect of which was striking and rather formal. Both these islands have evidently derived their names from their flat and truncated appearance. Table Island is a long and narrow ledge, two miles in length, and presenting a dead-level surface, elevated 200 feet above the sea, this flat table being supported upon a row of short basaltic columns. Tablet Island is very similar in character also; and in both of these islands the ground slopes outwards from the bases of the columns, forming a talus of *débris* arising from their disintegration from above, as is the case at the Giant's Causeway. As we skirted the south shore of the large island of Ponghou, I could also perceive basaltic columns in many places, often with a sandy beach at their base; and on approaching Pong Point, the south-west promontory, I observed the columns to be broken off upon the beach, forming distinct causeways in two places. The columnar structure is everywhere very distinct, and the phenomena similar to those met with on the Antrim coast, but on a less gigantic scale.

None of these islands are much more elevated than Table Island; and the soundings around them vary between 30 and 50 fathoms. They are all more or less flat, and entirely devoid of trees or even shrubs.

Hai-tan Island, to the north-east of Formosa, is really a portion of the coast of China. The seaward coast of Hai-tan Island consists of perfectly bare rocks, which descend in smoothly rounded surfaces to the water's edge. The island appears to be a mass of whinstone, with nothing better to relieve the eye than sandy patches and one or two remarkably conspicuous hills of sand.

Between Hai-tan Island and the mainland are numerous rocky islands of a remarkably bold outline. On two of these I landed— viz. on Middle Island, on the east side of the strait, and Black Islet, on the west side. Middle Island is formed of blocks of trappean rock piled up promiscuously and at various elevations to about 80 feet above the sea, the upper part being much disintegrated, and forming a coarse barren soil, which supports a few flowering plants and a scanty herbage.

Black Islet, within sight of the last, is a mass of granite, broken up and much disintegrated, all the upper surface being a soil of coarse quartz sand.

Immediately to the north of Formosa is a group of three islands, called Pinnacle, Craig, and Agincourt Island respectively. The

first of these, Pinnacle Island, is a perfectly bare, craggy rock, with a pinnacle at either end. The rock was whitened with the dung of sea-birds; and as we could not land, I was unable to determine with certainty its mineralogical composition.

The other two I had better opportunities of observing. The whole of Craig Island is a mass of trachytic lava broken up into smallish rough masses, even to the very summit. These blocks, upon the seashore, are very large, and piled up in picturesque confusion. On the eastern side is a series of pinnacles, or *aiguilles*, forming natural arches. They appear to be portions of a trap-dyke running out into the sea.

The third island of this group is Agincourt Island, the appearance of which is very remarkable from the numerous caves in its sides visible at a considerable distance; and its structure is on a near inspection easily discernible. The island is a rounded hill of sandstone with several smoothly worn eminences, but traversed by an enormous dyke of trappean rock. This dyke, seen best on the north side, is broad and nearly level, terminating in an abrupt precipice on the left, and gently sloping to the sea on the right hand. It cuts off a small portion of the sandstone rock from the main mass; and in this portion are two conspicuous caves. There are no less than six caverns in this island, nor are they all confined to the soft sandstone; two of them are in sandstone on the north side, and two in the sandstone of the south side. In all these the arches were broad and sweeping. The other two caverns were situated in the face of the trap-cliff of the eastern side of the island; and these were lofty and irregular in form, and quite distinct in character from the rest.

Beyond these, seventy-five miles to the eastward, is another group, consisting of Tia-usu, Hoa-pinsau, and Pinnacle Island, forming one group, of which the first named is composed of trappean rocks with a bold outline and rising nearly 1200 feet high; and Pinnacle Island derives its name from the remarkable forms which the most elevated and prominent rocks assume, and which have all the aspect of buildings, lighthouses, &c.

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3. *On some* SOURCES *of* COAL *in the* EASTERN HEMISPHERE, *namely* FORMOSA, LABUAN, SIBERIA, *and* JAPAN. By CUTHBERT COLLINGWOOD, M.B., F.L.S.

(Communicated by the Assistant-Secretary.)

[Abridged.]

THE Formosa coal-district is situated near Kelung, in the northeast corner of the island. The mines are a little more than a mile to the eastward of the town, upon the hills bordering on Quar-se-kau Bay. I approached them in a small boat up a muddy creek. On leaving the boat, we ascended a slight elevation passing a range of red sandstone hills, which formed a series continuous

with those seen at the back of the harbour, which dip on an average about 16° or 17° to the south-east. Indeed the whole country round Kelung is of red sandstone; and the weather-worn outcrops produce the undulating country, in the depressions of which the coal appears to have been deposited. By degrees we entered a blind valley, or *cul-de-sac*; and descending from the path into a ditch I stood at the entrance of the workings, which consisted of two small caverns at right angles to one another, hewn directly into the coal-seam, which at its outcrop was $2\frac{1}{2}$ feet thick. It rested upon a thin bed of stiff whitish clay, and was covered by a bank 40 or 50 feet high, composed of rubbly clay. The working was nearly level, and the roof so low that one could only get along by bending nearly double.

These mines appear to be worked in a very primitive manner. No shafts are sunk, nor is any machinery employed; but the coolies pick the coal, and convey it out of the working in small baskets. It is placed in boats, and conveyed to the harbour, where it is deposited in the coal-stores. These stores have no covering, nor any protection from the weather, and the coal is apt to deteriorate if kept there long. The mines are exclusively worked by the Chinese authorities, and by Chinese coolies.

The position of this coal-bed proves that it is of comparatively recent formation. It lies apparently over the sandstone. I may also mention that about the middle of this portion of the island, near the town of Sikkow, I observed a thin seam of indifferent coal, cropping out in the river's bank, over which was a bed of stiff clay, abounding in large oyster-shells, seven or eight inches long, of a species (probably the recent *Ostrea Canadensis*) which I have seen brought to Canton in vast numbers for the purposes of lime-making.

The Kelung coal is of very light weight, it burns very rapidly, and it gives out a very great heat, so much so that it readily sets the funnel on fire. It is extremely dirty; and the combustion is so imperfect that a vast number of blacks, of a soft and soiling character, fall all over the ship. The flues also rapidly get very foul, requiring frequent attention and cleansing. It leaves no less than 50 per cent. of ash; so that although it appears so cheap, it is not really more so than other coal, which has more substance and less waste.

There are some interesting points of resemblance between the coal-field at Kelung and that which is being worked by English enterprise, and in a much more business-like manner, at the British island of Labuan, off the west coast of Borneo, which I have since visited. The Labuan coal-field is situated in a dense jungle, from which it crops out so conspicuously, not far from the sea, that there is no wonder that it attracted attention. The coal-district is composed for the most part of a soft yellow sandstone, which dips 33° north by east; and the coal exists in several seams, of which the lowest is 11 feet 4 inches thick, though the quality of this seam is by no means the best. The coal-roof is a stiff blue clay (not fire-clay); and alternating with the seams are beds of shale. The highest (No. 1) seam is 4 feet 6 inches in thickness; No. 2 is 2 feet

9 inches; No. 3, 3 feet 9 inches; and No. 4, 11 feet 4 inches. Above No. 4 is 8 fathoms of grey shale, in which fossil shells are occasionally found; but I had great difficulty in procuring any fossils; none appear to have been kept. I succeeded in getting two bivalves from this grey shale.

There are two shafts at present constructed—one (the shallow pit) entering the No. 1 seam, and the other 45 fathoms deep; but a third is being dug, which will reach the depth of 100 fathoms; and there are besides seven or eight level workings.

It is very difficult to get labour sufficient to develop the resources of the mines; and although 600 men are on the books—Chinese, Malays, Klings, &c., with European departmental superintendents, only 300 are at work at a time. Eighty tons *per diem* are produced, and conveyed down a tramway, less than a mile long, to the coaling-pier; but with more labour, I was assured by the manager that they could easily produce 200 tons *per diem*.

The quality of the Labuan coal is superior to that of Kelung. It is a heavier, close-grained, and tolerably clean coal, very free from sulphur, and forms but little clinker, in this respect having a conspicuous advantage. It burns, however, very fast, and gives out a considerable heat, so much so that it is necessary to be careful that the red-hot flues are protected and watched, while the flames issuing from the funnel extend sometimes six or eight feet and endanger the rigging. In burning it produces a large quantity of soot and of imperfectly consumed fragments, which cover the ship, rendering everything filthy and dirty. Still it is better than Kelung coal.

The quality and geological relations of the Labuan coal seem to point out that it, like the Kelung coal, is a recent formation—in fact, a *lignite*. In the stiff clay roof of certain of the seams, Mr. Low, of Labuan, assures me that he has found many impressions of leaves, in very perfect preservation, identical with those of trees at the present moment growing in the jungle. In the coal there are very frequently found tears of pure Dammar resin; and the Dammar pine is still a common tree. This resin has also a remarkable tendency to occur in veins; and Mr. Sinclair, the manager, informed me that on one occasion a mass of pure Dammar, 6 lbs. in weight, was discovered.

Both at Kelung (Formosa) and at Labuan *petroleum* is found in the immediate vicinity of the coal-districts. In Kelung, or near, there are sources of petroleum which have not yet been worked. The Chinese have an idea that some parts of Formosa are rich in gold; and undoubtedly gold has been found there.

In Labuan, a petroleum spring exists, not far from the mines, in a "nullah" or deep ravine in the jungle. A pathway through the forest has been cleared to this spot, but up to the present time no workings have been undertaken. Other petroleum springs are also known to exist in the neighbourhood.

The Russians possess good coal at Possiette, situated on the coast at the southern point of Eastern Siberia, and at Dui, on the island of Saghalien, at the head of Castries Bay. The latter is a convict set-

tlement; and the coal is worked by the convicts, and used by the Russians solely for their own men-of-war.

This coal is small, but of excellent quality, and presents longitudinally a conchoidal and transversely cubic fracture, similar in character to Welsh coal, and produces when burnt a moderately dense dark-brown smoke. Mr. James Gillies, chief engineer of H.M.S. 'Scylla,' informs me that its steaming qualities are equal to Newcastle coal, and he believes that, owing to its caking-qualities, it would burn very well mixed with any small Welsh coal which would be too small to burn by itself. It cakes readily after having been in the furnace for a few minutes, and on being lifted with the poker it breaks up into large pieces of coke which throw out an intense heat. It burns very quickly, and if under easy steam leaves very little ash. Amount of ash, cinder, and soot in Dui coal 20 per cent.

The Possiette coal presents a vitreous fracture, more resembling that of English cannel coal. It is very bituminous, and burns quickly. But though it is of fair quality, it leaves a large residue of whitish-brown ash, with a moderate quantity of clinker. The deposit of soot in the tubes is very much greater than is produced by Newcastle coal—ash, clinker, and soot together amounting to from 24 to 28 per cent. Mr. Gillies, however, tells me that, owing to the small quantity of this coal which he took on board, and to its having been partially mixed with Welsh coal, the percentage of ash can only be regarded as an approximation. The Dui coal appears to be a lignite.

Japan also produces several kinds of coal, concerning which very little is known. Owing to the small quantities produced, the Daimios will not let them be sold for public use; and it is therefore difficult to test their qualities. Opportunities of examination have, however, been made use of by the engineers in H.M. navy; and the following results have been obtained by Mr. John Rice, chief-engineer, Royal Navy. There are five distinct kinds, known under the names of Gorio, Hirado, Korkora, Emakbodkh, and Korgah, which appear to possess good qualities,—and several others, respectively designated Miki, Omura, Yanagana, Ani, Suki, Karats, Chó-fu, and Chó-siu, most of which are very inferior, forming an immense quantity of clinker, and unfit for steaming-purposes, though they are no doubt valuable for domestic uses.

Korkora coal is of two qualities—one an inferior dirty brown substance, showing thin red layers when broken, and, like all those just referred to, conchoidal in fracture. The better kind of Korkora is bright, clean, and hard, liable to form clinker, so that it has been found desirable to increase the apertures between the fire-bars in the ordinary tubular boilers; it resembles Sydney coal in appearance, and appears to have a waste, consisting of ash, soot, and clinker, amounting to 30 per cent.

Korgah coal, very recently brought to Nagasaki, is very similar to it in appearance and quality.

Emakbodkh coal shows also clayey layers, and conchoidal laminations of a white calcareous substance, either carbonate or sul-

phate of lime.   This scaly appearance is characteristic.   It burns well, though with much smoke; but the clinker is lighter and better burnt than in some species.

Hirado coal is either hard or soft.   The soft kind cannot be used for steaming, because it becomes reduced to powder by being shaken up in the bunkers; otherwise it is a good coal.   Of the harder coal there are two varieties :—one abounding in earthy matter and silica, the clinker of which is covered with a vitreous glaze; and a second and better kind, resembling Welsh coal, being bright in appearance, and containing about 72 per cent. of carbon.   The fracture is cubical.   The percentage of waste is considerable, amounting to 32; and the consumption would be equal to about $\frac{1}{4}$ more than the best Welsh coal, with which, however, it might be very advantageously mixed.

The best of these Japanese coals is that known as Gorio.   It is a clean, hard, cubical coal, resembling Welsh in appearance, and containing 73 per cent. of carbon.   But small quantities, however, have been brought to Nagasaki; and it has unfortunately happened that, in consequence of the heavy rains, the Gorio mine has fallen in, and some time must elapse before the old workings can be again made use of.

I must not conclude these remarks without reference to a remarkable coal which has been brought in small quantities from Ivanai, in the north part of Nipon, where there appears to be a large mine of it.   The Daimio to whom this coal belongs is not friendly to foreigners, and therefore the coal is difficult to be procured.   This coal is worked by the Japanese.   It is a very clean, highly bituminous coal, and will burn with flame in the light of a candle.   It appears, like the rest, to be a lignite*.

* [The paper was illustrated by specimens of various rocks and of the coals of Formosa, Labuan, Dui, and Ivanai, which the author presented to the Society.—EDIT.]

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPERS.

1. *On the* Amiens Gravel.
By Alfred Tylor, Esq., F.G.S.

(Read Nov. 8, 1867*.)

[Plates III. & IV.]

Contents.

I. Introduction.

The exact position, character, and equivalents of the Quaternary deposits of the valley of the Somme have been frequently discussed. On the authority of certain sections and plans of Amiens and Abbeville, the correctness of which will be examined hereafter, theoretical views concerning the relative ages of different parts of the gravel and of different parts of the valley of the Somme have been promulgated by Mr. Prestwich, and repeated by Sir C. Lyell and others. These geologists have asserted :—

First, that there were two valley-gravels of distinct age at Amiens and Abbeville, one named by them the upper and the other the lower valley-gravel ;

Secondly, that the upper gravel was the older of the two ; and

Thirdly, that the valley of the Somme was excavated to a depth of 40 or 50 feet since the deposition of the upper valley-gravel, and previously to the deposition of the lower valley-gravel ;

Fourthly, that both gravels were fossiliferous, and contained the remains of man, or rather human implements, and bones of extinct mammalia, the lower gravels having the greater number of species of mollusca, the higher gravels containing the greater number of flint implements ;

* For the Proceedings at this Meeting see p. 1.

Fifthly, that the height of 70 feet, at which fossiliferous gravels now stand above the level of the Somme, is much beyond the limit of floods, and therefore that these gravels could only have been deposited at St. Acheul before the river-channel was cut down to its present level.

The general effect of these assertions was to refer the remains of man found in St. Acheul back to an indefinite date, separated from the historical period by an interval during which valleys were excavated or deepened 40 or 50 feet.

In a paper read before this Society in April 1866*, I suggested that there was evidence of very little weathering or atmospheric action since the date of the drift containing human remains, and that the age of these deposits was close to the Historical period,—also that the upper and lower valley-gravels in the Somme were continuous and of one period.

I afterwards read, in June 1866, a statement of what I believed to be the correct interpretation of the Amiens and Abbeville sections, reasserting the continuity of the gravel-deposits on gradual slopes from the higher to the lower levels in the valley, except in rare cases or isolated spots, where the continuity was interrupted or prevented by some upstanding piece of the original rock out of which the valley had been cut, in which case the gravel wraps round the base of the upstanding knoll of chalk. I quoted the section at Montiers as one that shows a direct sequence of gravel from above the railway to the Somme, notwithstanding the version of that locality published by Mr. Prestwich, in which chalk is represented in a position where I could only find gravel.

At the same time attention was drawn by me to the probability of the brick-earth terrace sloping down to the Lea Marshes at Clapton being of the same age as the similarly formed Loess terrace sloping down to the Somme at Amiens. I also asserted that there was good evidence in the direction and gradient of the terrace, in the configuration of the gravel and brick-earth and of the London-clay surface at Clapton, of the water having occupied the whole valley of the Lea at the time of the formation of this Clapton terrace, and also of the water of the river Lea or other rivers having reached very much higher levels in the vicinity at that period, while the Stoke-Newington and Highbury gravels and brick-earth were being deposited.

I still hold these opinions, and am prepared to demonstrate their truth ; and I ask the attention of the Society to a restatement of the exact geological facts to be seen in the Somme valley, and to evidence quite independent of that which has been previously submitted to the Society, although to a certain extent going over the same ground.

The conclusions that I arrive at are extremely dissimilar to those of Mr. Prestwich and Sir C. Lyell, and are as follows :—

First, that the surface of the chalk in the valley of the Somme had assumed its present form prior to the deposition of any of the

* Quart. Journ. Geol. Soc. vol. xxii. p. 463.

gravel or loess now to be seen there, and in this respect corresponded with all other valleys in which Quaternary deposits of this character are met with.

Second, that the whole of the Amiens-valley gravel is of one formation and of similar mineral character, and contains nearly similar organic contents, the La Neuville, Montiers, and St.-Acheul gravels being of the same age, and capped with a covering of loess also of one age and mineral character, the whole deposit being of a date not much antecedent to the Historical period.

Third, that the gravel in the valley of the Somme at Amiens is partly derived from *débris* brought down by the River Somme and by the two rivers the Celle and the Arve, and partly consists of material from the adjoining higher grounds, washed in by land-floods,—the immense quantity of chalk present in the gravel having been derived from the latter source. It is where the surface of the chalk is concave that the gravel is thickest.

Fourth, that the quaternary gravels of the Somme are not separated into two divisions by an escarpment of chalk parallel to the river as has been stated. They would have formed an exception to other river-gravels if this had been the case. The St.-Acheul gravels thin out gradually as they slope from the high land down to the Somme, and they pass away into the Loess formation,—and so also at Montiers.

The Loess deposit, on the contrary, forms a distinct escarpment for many miles along the Somme; and this, I believe, is the bank of the ancient river whose floods produced the St.-Acheul and Montiers gravels.

Fifth, that the existence of river-floods, extending to a height of at least eighty feet above the present level of the Somme, is perfectly proved by the gradual slope and continuity of the gravels deposited by those floods upon the sloping sides of the valley towards the Somme, and also by the Loess or warp, of similar mineral composition and colour, extending continuously over the whole series of gravels, and finishing with a well-defined bank near the present stream.

Beds of gravel, brick-earth, and loess, having an even sloping surface from the escarpment of the sides of the valley down to the terrace near the river-bank, are often to be observed near other rivers whose channels bear the same proportion to their valleys that the Somme river bears to its valley, and where gravel- and loess-deposits reach to a height of 100 feet above the present river-levels.

Sixth, that many of the Quaternary deposits in all countries, clearly posterior to the formation of the valleys in which they lie, are of such great dimensions and elevation that they must have been formed under physical conditions very different from our own. They indicate a Pluvial period, just as clearly as the northern drift indicates a Glacial period. This Pluvial period must have immediately preceded the true Historical period.

Since June 1866 I have visited Amiens several times, and compared the gravels as accurately as I could, both as to situation and

character, with those of other rivers, of which I have had surveys made; and I hoped to have brought the whole subject of valley-gravels before the Society in the early part of 1868.   The announcement of the intended absence from England of Mr. Prestwich has induced me to describe the Amiens gravels first, in order to have the advantage of his presence at the meeting, reserving my account of other river-gravels and general comparison to a future paper.

The plan and sections of the Quaternary deposits at Amiens illustrating this paper will, I hope, make the actual geographical and geological positions of the Amiens beds quite clear.

It should be mentioned that, in August 1866, after examining the levels myself, I called at the railway office at Amiens to obtain the precise height of the different points on the railway above the sea, and to get the name of a competent surveyor, and was referred to the chief engineer, M. Guillom.   That gentleman only saw me for a few minutes, but kindly promised that if all the points on which I required information were laid down on a plan, he would have the sections carefully taken for me in a few weeks.   This plan was accordingly sent to him by me a few days afterwards, with the lines marked on which I wished the levels.

The work was more tedious than was expected by M. Guillom, and he did not send me the measured sections until May 1867.   The levels of these sections have been taken with the greatest care, and, I believe, are as precise as any that have been taken for geological purposes; and I am therefore indebted to M. Guillom for the means of drawing an exact picture of the surface of the chalk prior, as I believe, to the deposition of any of the valley-gravel or loess at Amiens.   The value of this communication therefore much depends on M. Guillom's survey.

The heights on the maps and sections are in English feet, the datum line being mean tide at Havre.   The scale of the plan (Plate III.) is $3\frac{1}{6}$ inches to a mile.   The vertical scale in Plate IV. is $\frac{1}{2}$ inch to 55 feet, and is three times the horizontal scale.   The dotted lines on the plan show the position of five sections, I K, R S, L M, N O P, N Q, nearly at right angles to the river, some of them extending to a height of 200 feet above the sea.   The line A B is along the Imperial Road.   See Plates III. and IV.

II. Description of the Longitudinal Section.

There is also a longitudinal section, divided into three parts on account of the public buildings at St. Acheul preventing continuous levels being taken.   The divisions are C D, E F, and G H; but it will be treated sometimes in this paper as one section, C H.   See Plate IV. figs. 3, 4, and 5.

It passes through the celebrated pits of St. Acheul, and is bounded by the River Arve, a tributary of the Somme, at its eastern point, C, and by the escarpment of chalk in the Rue de Cagny (700 yards west of the railway-station, Amiens) at its western extremity, point H.

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PLAN OF
AMIENS
AND ITS VICINITY,
illustrating Mr Alfred Tyler's Paper on the Amiens Gravel.

The Position of the Gravel Pits is only approximate
as also is that of the Saveuse Valley.

1 Mile

EXPLANATION.
Chalk Escarpment
Gravel Pits
Marsh
Lines of Section
Loess & Gravel
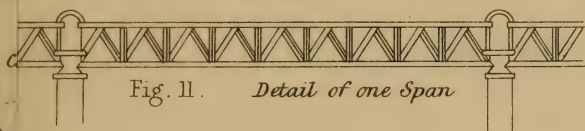
CHEM

Quart. Journ. Geol. Soc. Vol. XXIV. Pl. IV.

Fig. 5. Section along the line. G. H.

ong Acheu
vel Pit *Acheul large Pit*

Fig. 11. Detail of one Span

←---------- 80 feet ----------→

Fig. 10. Section of a Bridge 16 Miles east
of Kurrachee on the Sinde Railway

←-------------- 1600 feet --------------→

Girder 65 feet above the level of Water at Kurrachee

Edges of
y Floods   S a n d
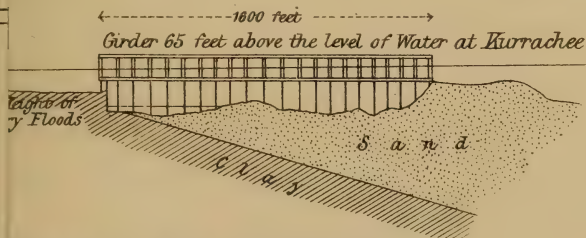
osed on the North East side of the
heul Gravel Pit

Roman Graves   150 E
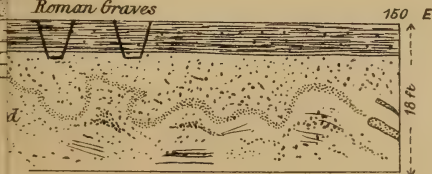
uth bank of the Imperial Road between the
Acheul, 100 yards long 11 feet high.

144 W

SECTIONS IN THE ENVIRONS OF AMIENS, PRINCIPALLY SURVEYED BY M.GUILLOM CHIEF ENGINEER OF THE CHEMIN DE FER DU NORD.

To illustrate Mr Tylor's paper on the Gravel of Amiens

Quart Journ Geol Soc Vol XXIV Pl IV

Fig 1. Section along the Tramway, from the Imperial Road east of St Acheul to the Railway.
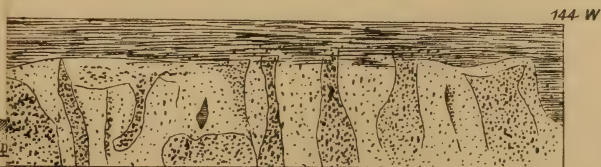
Fig. 2. Section from the Imperial Road to la Neuville Ballast Pit, along the line

La Neuville Ballast Pit
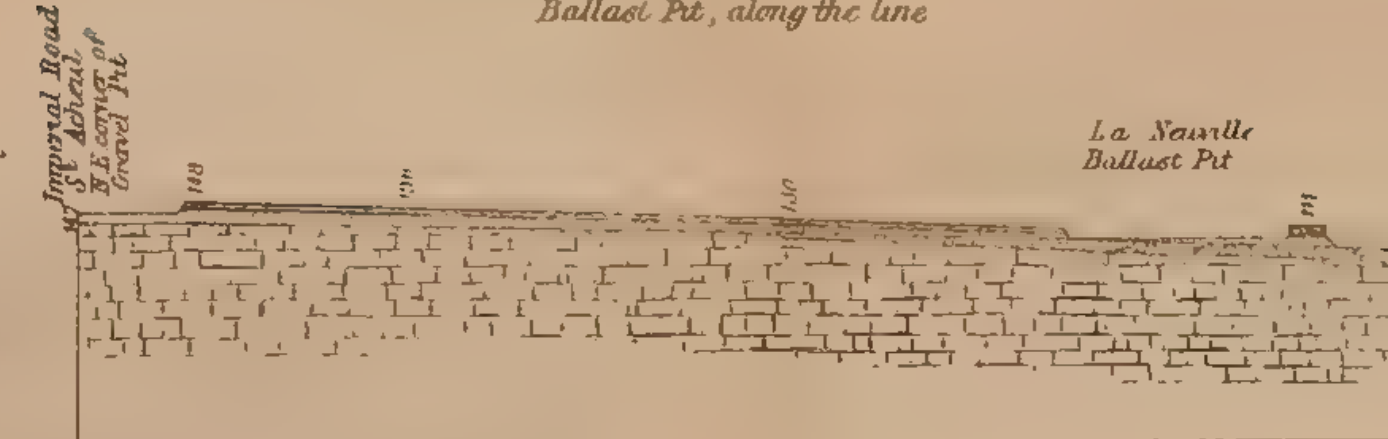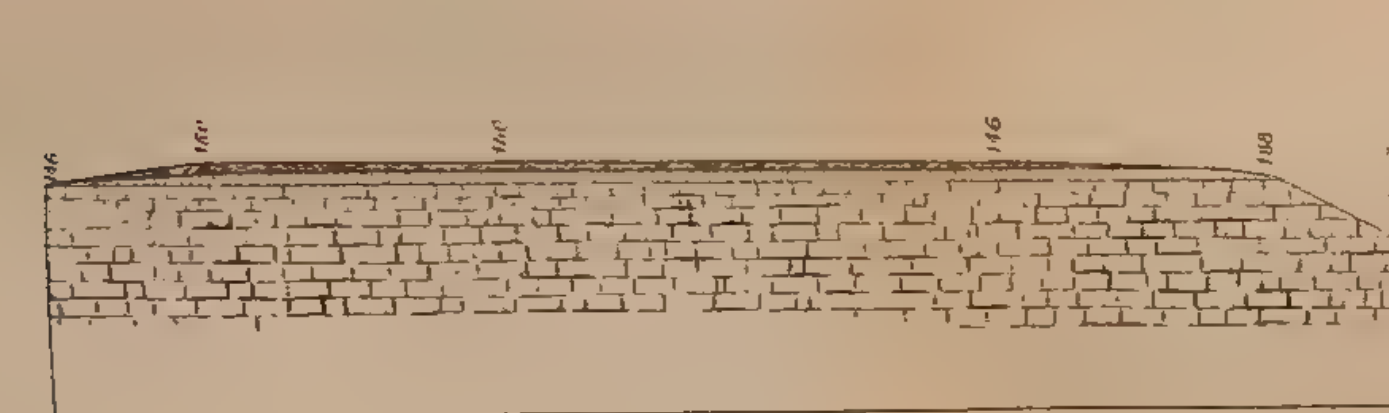
Fig. 3. Section along the line. C. D.

St Acheul Gravel Pit
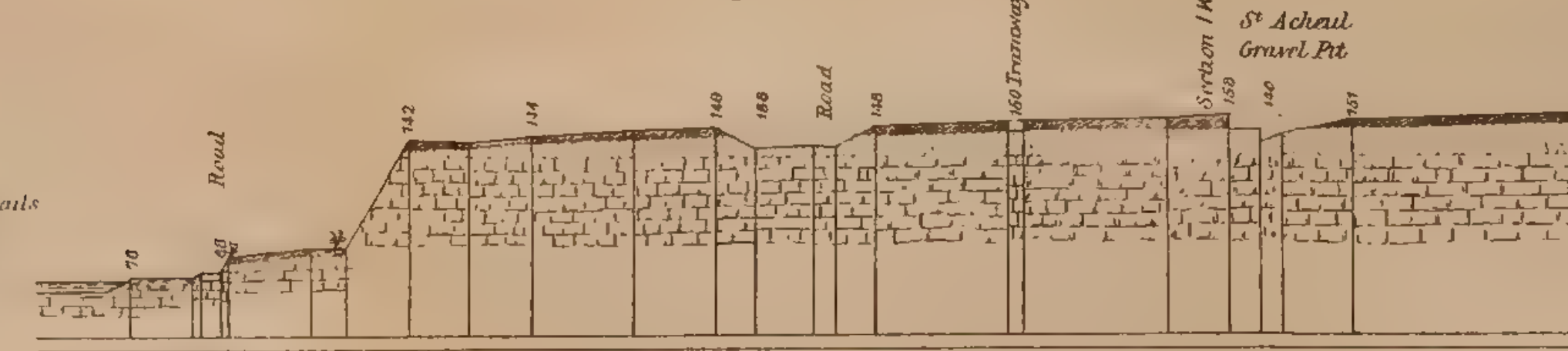
Fig. 4. Section along the line E. F.

St Acheul

Fig. 5. Section along the line. G. H.

St Acheul large Pit
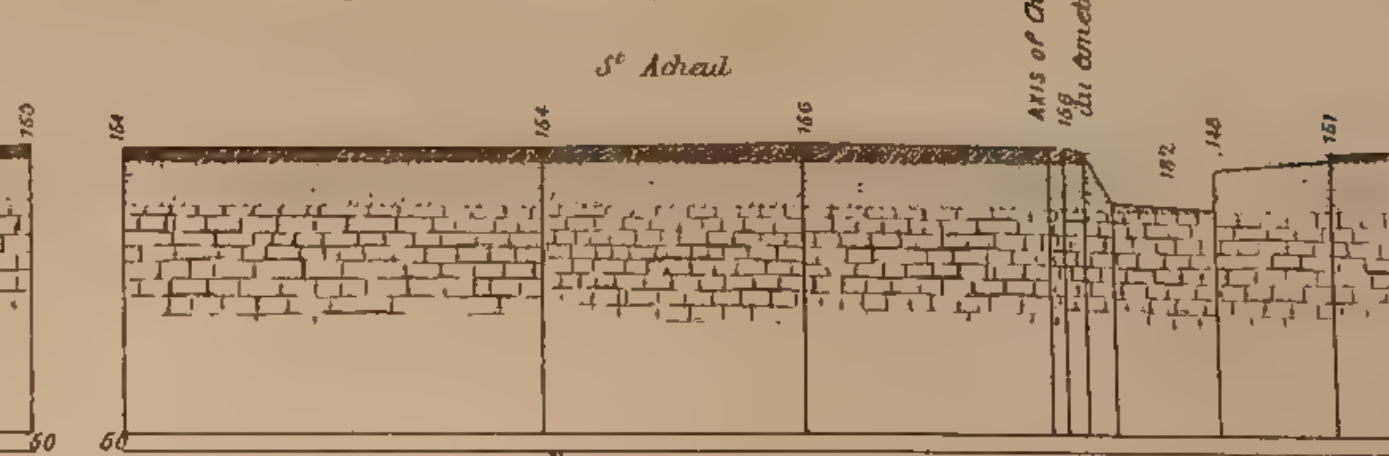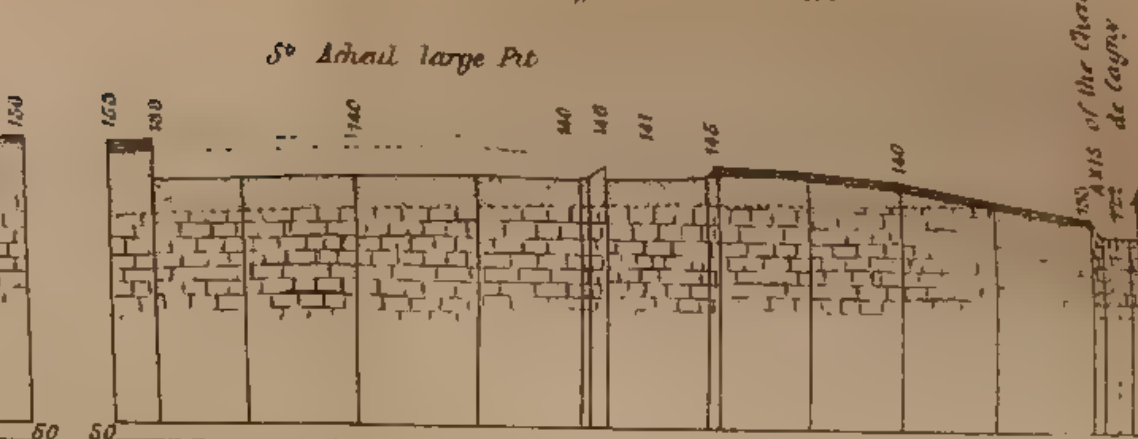
Fig. 6 Section along the line I K.

La Neuville

Bras de la Somme
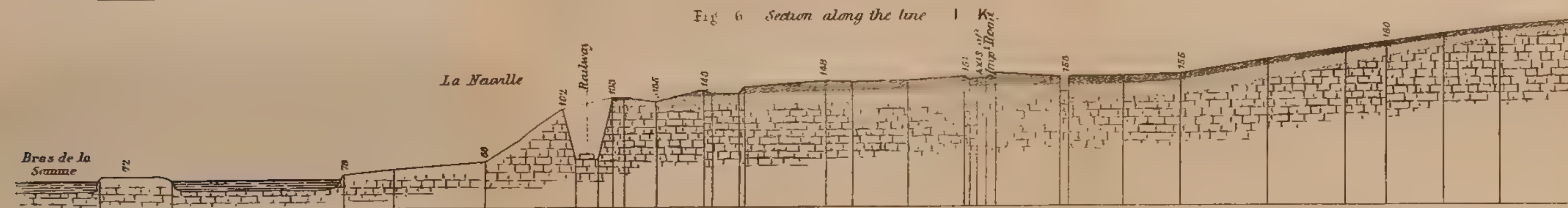
Fig 7. Section along the line. L. M.

R. Scance — La Neuville — Chalk Pit

Montiers large Gravel Pit
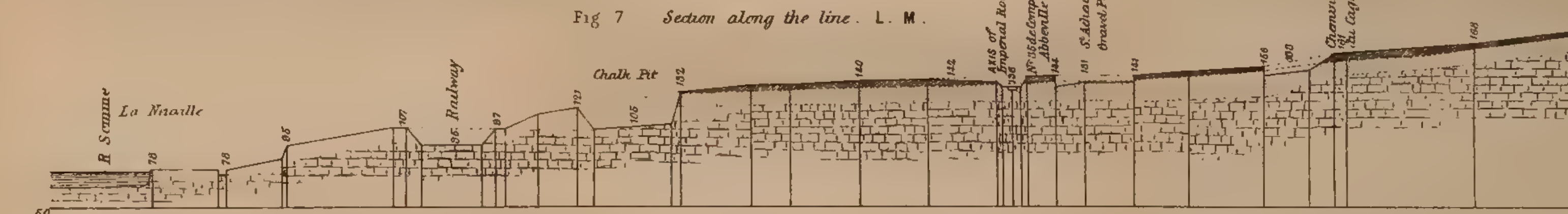
Fig. 8. Section along line N O. P.
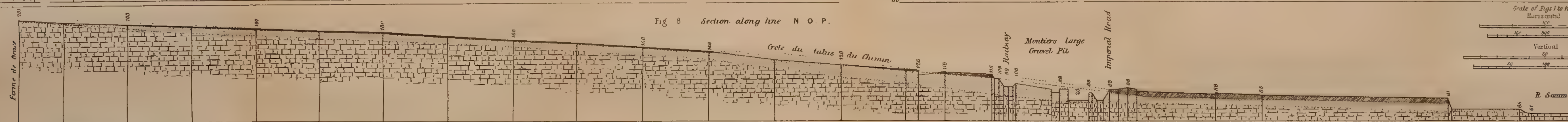
Ferme de Grace
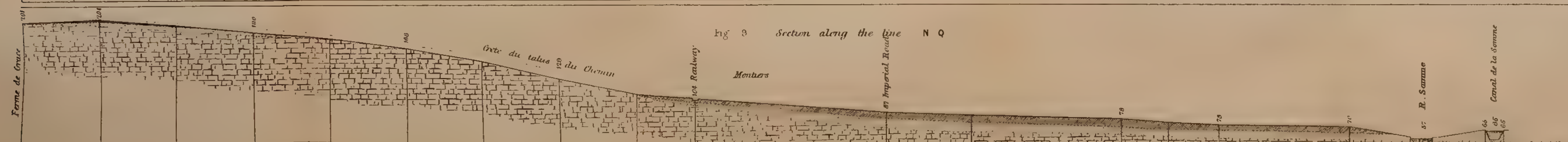
Crête du talus du Chemin

Fig 9. Section along the line N Q

Ferme de Grace

Crête du talus du Chemin

Montiers — Imperial Road — R. Somme — Canal de la Somme

Fig 10. Section of a Bridge 16 Miles east of Kurrachee on the Sinde Railway.

Fig. 11 Detail of one Span

Girder 65 feet above the level of Water at Kurrachee
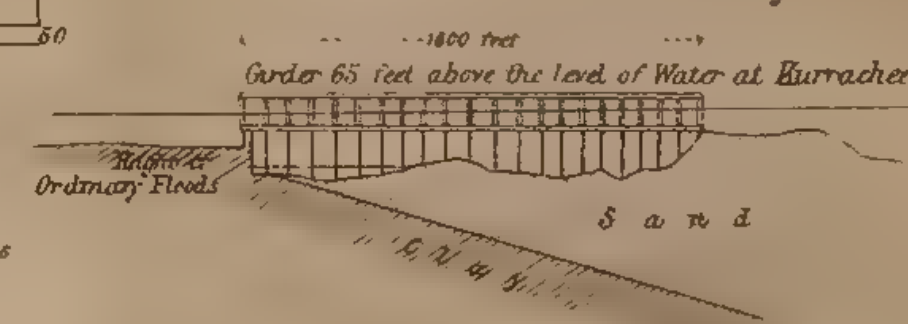
Fig. 12. Section exposed on the North East side of the St Acheul Gravel Pit.

R. Somme — Roman Graves — Shell Bed
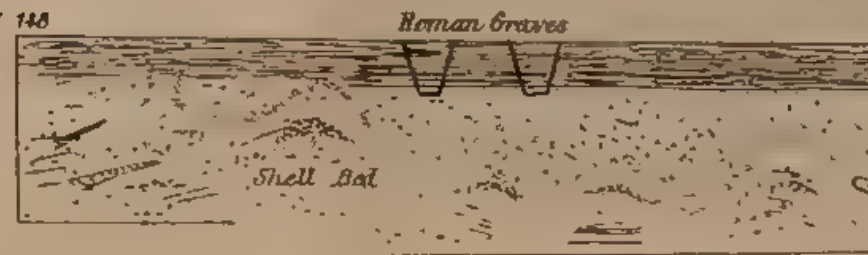
Fig. 13. Section along the South bank of the Imperial Road between the Rue de Cagny and St Acheul, 100 yards long 11 feet high.

Scale of Figs 1 to 11
Horizontal
Vertical

Loess
Gravel
Chalk

C H is near the Imperial Road, and is parallel to that road, to the railway, and to the River Somme.

Section G H.—The length of G H is 1400 feet. See Plate IV. fig. 5. The highest point is 157 feet above the sea, 79 feet above the River Arve, 3 feet over the highest part of the Imperial road, 61 feet above the rails, and 84 feet above the River Somme at Neuville. The gradient, commencing at point H, 129 feet above the sea, Rue de Cagny, rises to the east 1 in 30, then 1 in 33, 1 in 35, 1 in 61, and 1 in 100, reaching the well-known section of St.-Acheul Pit, with Roman graves, fossiliferous sand, and wavy marls, at a height of $152\frac{1}{2}$ feet above the sea. A portion of this is shown in Plate IV. fig. 12.

The loess in this section is four feet at the highest and most easterly point, G, gradually thinning to the west, and ceasing when it reaches H.

The gravel is sixteen feet thick at its most easterly point, G, thinning out as it passes to the west a little before the loess disappears.

The surface of the chalk is 133 feet above the sea at G, and 128 feet at H. The surface falls 1 in 280 to the west.

Section E F.—The surface gradient commences at F, at a height of 156 feet above the sea, and it passes the Cemetery Road on the level, and rises at a gradient to the east of only 1 in 700, then falls to the east at 1 in 165 and 1 in 701, reaching the point E at a height of 154 feet above the sea (Plate IV. fig. 4).

The loess is 4 feet at F, thickening to 5 feet at the summit-level of the whole section C H, and then thinning out to 4 feet at E. The regularity of the loess is a very important fact.

The gravel is 17 feet thick at F, and 15 feet at E. The surface of the chalk is 133 feet above the sea at both E and F, showing a perfectly horizontal line, while there is only a variation in the level of the surface-loess of 3 feet in this section, which is 1586 feet long.

Section C D (Plate IV. fig. 3).—Section C D commences at D with an elevation of $153\frac{3}{4}$ feet above the sea; and the gradient falls east at 1 in 157, then rises to the east 1 in 80, then falls to the east 1 in 40 and 1 in 300. Here the tramway (Plate IV. fig. 1) crosses the Imperial Road, and some very extensive gravel-pits are now being worked for ballast.

The gradient continues falling east 1 in 88, 1 in 180, 1 in 160, 1 in 41, 1 in 33, and rising 1 in 200 to the east, where it reaches the escarpment at a height of $142\frac{1}{4}$ feet above the sea. The loess is here 5 feet thick, and the gravel 2 feet, according to M. Guillom's survey; but I found only two or three feet where I observed it. The loess is 5 feet thick near the tramway, and 4 feet at the point D. The gravel is 13 feet thick at D, and 10 feet thick at the tramway, thinning out as it approaches the escarpment on the east, as it did on the west. The surface of chalk is horizontal throughout this section also up to the escarpment.

At the escarpment the chalk falls to the east $52\frac{1}{2}$ feet in a distance of 106, or at an angle of 45° and gradient of 1 in 2 nearly. The line

of slope of this escarpment is remarkably straight in many places, and quite free from gravel or loess. Then there follows a flat terrace of loess, 60 feet wide, then a slope towards the river, of 1 in 30, and then 1 in 4, until we reach the marsh at a height of $76\frac{1}{3}$ feet above the sea.

III. Descriptions of the Transverse Sections.

Section I K (Plate IV. fig. 6).—This section commences at the Rue de Cagny, point I, at a height of 200 feet above the sea, and falls to the river and the north at a gradient of 1 in 32, 1 in 28, 1 in 22, 1 in 18, 1 in 54. It then rises to the north at 1 in 162, and crosses the tramway ballast-pit at a level of $153\frac{1}{2}$ feet above the sea, and the Imperial Road at a height of 153 feet above the sea ; it then rises to the north at a gradient of 1 in 20, reaching 156 feet above the sea, then falls towards the river at 1 in 42, 1 in 100, rises 1 in 87, falls 1 in 67, 1 in 65, 1 in 50, until it reaches the railway-cutting, at a height of 138 feet above the sea. The cutting happens to be in the escarpment of the ancient chalk valley, in which the valley-gravel has been deposited; and the surface of the gravel follows the contour of the ground, and falls at a gradient of 1 in 8, and then 1 in 7, declining 47 feet in a distance of 360 feet. The surface then falls more gently to the river at 1 in 36, 1 in 34, until it reaches the Somme.

At the Point I in the Rue de Cagny the loess is 3 feet thick, and near the Imperial Road it is 8 feet thick ; at one point it gradually thins out towards the river and railway, and at the railway-cutting the loess is only 2 feet thick. I do not know the thickness on the north side of the railway ; but as the gravel thins out rapidly, the loess is no doubt from 10 to 12 feet thick in some points. The gravel at the point I is 5 feet thick ; it increases to 10 feet thick as it approaches the Imperial Road, and after passing that at a height of 148 feet above the sea it gradually thins away until it is only 3 feet thick at the south side of the railway-cutting, and soon merges into the loess on the steep incline on the north side of the railway.

The surface of the chalk at the Rue de Cagny near the point I is 195 feet above the sea ; it falls to 136 feet above the sea where it passes under the Imperial Road, and then becomes nearly horizontal, only falling 3 feet until it reaches the railway-cutting.

Fig. 1.—*Section at La Neuville, showing the Loess resting immediately on the Chalk.*
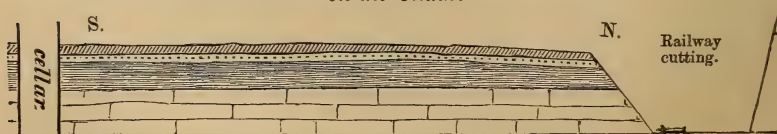
The slope then becomes rapid again, and it probably falls at a

gradient of 1 in 4 for some distance, and then becomes horizontal again at the River Somme.

The loess is clearly seen in the railway-cutting and at one cellar (Plate III. C*) in Neuville (fig. 1), resting on chalk without any intermediate gravel, C on the plan; but I have left the junction between the loess and gravel undefined in the lower part of the section I K, as I could not put the junction in accurately.

If a straight line be drawn from point I on the Rue de Cagny to K on the Somme, it will pass 32 feet below the top of the railway-cutting along the line I K, and it will pass over the chalk at the Imperial Road at a height of 17 feet, showing that the surface of the chalk between those two points is concave.

Section L M.—(Plate IV. fig. 7.)—This section commences at the point beyond the Rue de Cagny, at a height of 187 feet above the sea; the gradient dips northwards towards the river, and falls 1 in 37, until it passes the Rue de Cagny at a height of 160 feet above the sea. It passes through a part of the great St.-Acheul pit, with a gradient of 1 in 15, 1 in 40, 1 in 70, 1 in 130. Here it crosses the Imperial Road and falls to the north, with a gradient of 1 in 600, 1 in 300, 1 in 40, 1 in 688, 1 in 43, to the La-Neuville Railway ballast-pit close to the railway workshops, where it reaches a height of 132 feet above the sea. The ground is quarried out; but the surface apparently dipped north at a gradient of 1 in 12, then rose 1 in 33, then fell 1 in 7, horizontally crossing the railway-cutting at a height of 107 feet, $11\frac{1}{2}$ feet above the rails.

The ground then falls north, at a gradient of 1 in 21, forming the top of the loess terrace, at 95 feet above the sea. The escarpment of the loess terrace is here at a very steep angle, falling 12 feet in a horizontal distance of 14 feet, then at a gradient of 1 in 71 to the first brook, then level to the Somme.

The loess is 4 feet thick at the Rue de Cagny, in the section L M, and the same thickness at the Imperial Road. At the escarpment of the chalk it is only 2 feet thick, and seems to appear again at the terrace in considerable thickness, at a height of 95 feet above the sea.

The gravel is 13 feet thick at the Rue de Cagny, nearly 20 feet thick in the St.-Acheul pit, and runs out to 6 feet at the Railway-works ballast- and chalk-pit at the escarpment. I have no section of gravel further north than this pit.

If a straight line be drawn from the Rue de Cagny to the Somme, along the line L M, it passes the Imperial Road on the level, and is 15 feet below the surface at the Railway-works ballast-pit; so the surface is convex at that point.

The convexity of the chalk on the same line is 14 feet at the ballast-pit.

Section N O P.—(Plate IV. fig. 8.)—This section commences at the Ferme de Grâce, point N, at a height of 201 feet above the sea, and goes along the road to Montiers by the line N O P as far as O.

* The letter C in La Neuville must be distinguished from the letter **C** in Longueau on the same Plate III.

The first gradient is 1 in 33, north; 1 in 90, 1 in 100, 1 in 105, 1 in 110, 1 in 110, 1 in 110, 1 in 57, 1 in 60, 1 in 70, 1 in 60. Here it crosses the junction of two roads at a height of 155 feet above the sea. Then follow on north 1 in 60, 1 in 27, 1 in 40, 1 in 60, to the point O, at a height of 120 feet above the sea; then 1 in 30 and 1 in 75 to the railway, 1 in 33 to the Imperial Road, then 1 in 56, 1 in 50, 1 in 231, and it crosses the top of the escarpment of loess at a height of 81 feet above the sea. Then the face of escarpment falls 16½ feet in 18 feet, then is horizontal to the river.

If a line be drawn from the Point N to the River Somme along the line N O P, it will pass under the junction of two roads at a height of 142 feet above the sea, or 15 feet under the roads. It will pass 10 feet above the rails, and 2 feet above the Imperial Road; so that the extreme convexity of the surface at any point of the line of 7458 feet is only 15 feet. This is important, as the section has been represented as enormously convex by previous writers.

The surface of chalk at the junction of the two roads is 142 feet above the sea, and is therefore only 6 feet above a straight line drawn through N O P. The surface at the junction of the two roads is very slightly convex. The surface of the chalk at the railway is 23 feet below a straight line drawn from the Ferme de Grâce 201 feet above the sea to the Somme (at a height of 61 feet above the sea); a straight line from the Ferme de Grâce, 201 feet above the sea to the Somme, 61 feet above the sea, passes over the railway 8 feet above the rails, and 23 feet above the surface of the chalk at that point; so that the surface of the chalk is concave to the extent of 23 feet. At the Imperial Road the surface of the chalk is concave to the extent of 22 feet, although on the upper part it is convex to the extent of 15 feet.

IV. CHARACTERS OF THE CHALK, GRAVEL, AND LOESS.

I will not trouble the Society with the details of Section N Q (Plate IV. fig. 8), but will now proceed to describe the characters of the chalk, the gravel, and the loess, as I have observed them near Amiens.

1. *The Chalk.*—The condition of the chalk itself near Amiens is remarkable in some places.

In a railway section near Pont de Metz, about three miles from Amiens and Montiers, the chalk surface slopes northward at an angle of 20°, and is overlain by 20 feet of drift sands dipping 10° N. where they touch the chalk, but filling up the concavities of the chalk, and having their upper surface sloping northward at an angle of 3°.

At Pont de Metz the chalk is covered with a drift chalk-marl, and with beds of chalk rubble and chalk pellets, with very little mixture of sand or clay, 15 to 20 feet thick.

Near Guigencourt, a quarry in the chalk on the plateau, about four miles south of Montiers, the chalk is very much split up by joints lying at an angle of eighty degrees, or very nearly vertical, and also nearly at right angles to the planes of bedding of the chalk. (Fig. 2.)

These joints are now in many cases fissures two or three inches wide, and extending to a considerable depth; but they are filled up with a fine brown loess, which seems as if injected into them; for I observed in one or two cases that a vein of two or three inches thick had entered a horizontal joint, and passed along that in a horizontal direction, thinning out to only half an inch. I give a sketch of this chalk-quarry. This system of joints would very much facilitate the

Fig. 2.—*Section exposed in a Chalk-quarry near Guigencourt.*
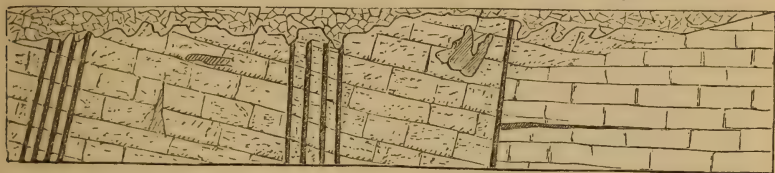
formation, or rather the separation, of the chalk into rectangular and imperfect spheroids, such as are seen in the quarries behind St. Acheul and Longueau, where some decomposing agency has acted upon the chalk itself with considerable effect.

In the drawing (fig. 3) made of the condition of the surface of the

Fig. 3.—*Section along the St. Acheul and Longueau Road.*

W.   E.

chalk (and to a depth of 20 feet) along the Saint-Acheul and Longueau road, running east and west, I found the sandpipes in the chalk very close together, and filled with brown loess and gravel. There are some large pipes in the eastern escarpment in M. Dailli's garden, close to the road; but they decrease towards Cagny on the escarpment of chalk trending southwards there exposed, and also in the escarpment of chalk trending northwards. (See fig. 4.) I did not observe any

Fig. 4.—*Section in M. Dailli's Garden showing decomposed Chalk.*

S.   N.
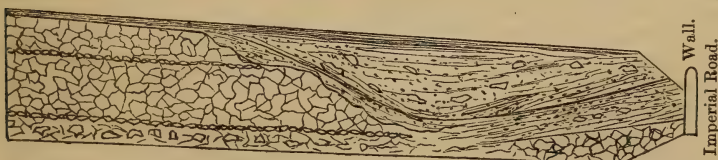
decomposed chalk in the railway-cutting or quarry between Longueau and La Neuville, nor at the ballast-pit in the chalk near La Neuville at the railway workshops, Amiens. The surface of the chalk, however, is irregular, and covered with gravel, but without deep pipes.

The drawings of the chalk-quarry, fig. 2, and in M. Dailli's garden, north of C, fig. 4, will explain the remarkable character of the decomposition that has affected the chalk. Not only has chalk been removed by the chemical action which bores pipes in it, but the loess appears to have followed closely, penetrating through the mass for many feet, occupying the vacant space made by the destruction of the calcareous matter in many places, or uniting with it, and making a kind of Combe Rock.

The harder pieces of chalk are left, often in a boulder-like form (as drawn), with slightly rounded or abraded corners, the chalk between large pieces then being loose and friable, and marly in colour, often mixed with loess, and with ferruginous stains. When the chalk is quarried, the large masses fall down like boulders, and are used for purposes of masonry, untouched by the quarryman. The hard pieces of chalk project beyond the soft matrix in which they are enclosed, like the flints upon the Brighton cliff, making a serrated face. The largest piece that has fallen out is only about three feet long, according to M. Dailli, who has quarried thousands of tons of chalk without meeting with a larger mass. There is a pipe, ten feet in diameter, in M. Dailli's garden, and the depression in the chalk at the north-east corner has a pipe-like form.

The lines of large flints which traverse the whole of the escarpment horizontally are perfectly *in situ*.

That this decomposition of the chalk *in situ* has some relation to the physical circumstances following the deposition of gravel at St. Acheul is, I think, probable, as some part of the drainage from above St. Acheul would pass through the escarpment in question in order to get to the marshes, and the action which has caused the removal of the chalk must have acted with great intensity on the high land adjoining, so that the current was from above downwards. About one-eighth of the St.-Acheul gravel consists of chalk in the form of large pieces averaging 4 inches diameter, ofc halk pellets from $\frac{1}{8}$ to $1\frac{1}{2}$ in diameter, and of chalk finely divided and mixed with clay.

Where we can see the chalk near C, it is so perforated by pipes and separated into small pieces that it seems prepared for a rapid denudation if attacked by water with any vigour ; and if this was the condition of the chalk also at higher levels near St. Acheul and Montiers, we can account for the large quantity of chalk contained in the Amiens gravels.

The fall of the Somme from Longueau to Montiers is fifteen feet, the river flowing from south-east to north-west nearly, at a gradient of only 1 in 1520. The rails are 96 feet at La Neuville, and 99 feet at Montiers, above the sea-level.

By referring to the sections, C D, E F, G H, which are parallel with the River Somme and the Imperial Road, it will be seen that on a line from east to west, 1644 yards long, from the eastern escarpment of the chalk east of St.-Acheul to the western escarpment of the chalk near the northern termination of the Rue de Cagny, the surface of the chalk is extremely regular and horizontal.

The highest point of the chalk on the line C H is only three feet higher than the lowest point on that line.

There is a steep escarpment, 50 feet high, at Longueau, of bare chalk facing the east, and an escarpment, 30 feet high, near the Rue de Cagny, of bare chalk facing the west. The outcrop of chalk is marked on the plan, in order to be well seen.

The contrary is the case with the sections from south to north. The escarpment of the chalk facing the River Somme is not so steep,

Fig. 5.—*Section of decomposed Chalk exposed in a quarry in the escarpment near* **C**, *with bank of Loess at the base.*
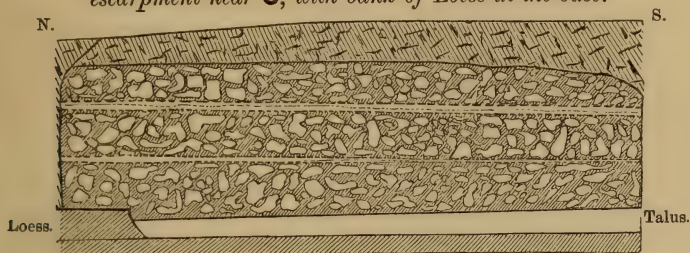
Fig. 6.—*Section showing the escarpment of Loess between the Quarry (fig. 5) and the Imperial Road.*
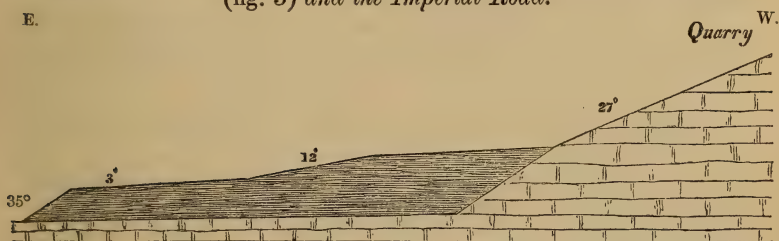
and is therefore nowhere bare, being covered with a Quaternary deposit.

The slope of the chalk from south to north is considerable when compared with the almost perfect horizontality of the chalk in an east and west direction.

Thus we have a slope or gradient of 1 in 33, or of $2\frac{3}{4}°$, beginning at the point L on the line L M, 175 feet above the sea, to M on the Somme, at a height of 76 feet above the sea. The distance is 3342 feet between L and M. These escarpments are evidently the sides of lateral valleys, and are not due to the action of the River Somme, but to that of smaller lateral and more rapid streams running into the Somme. The River Arve still approaches closely to the eastern escarpment of St. Acheul. The western escarpment of St. Acheul is the side of a valley now dry, but which evidently contained a rapidly flowing stream when the western escarpment was formed.

The gradient of the River Arve is much steeper than that of the Somme; but the valley at the west of St. Acheul formerly contained

a stream which must have fallen with great velocity, as the slope
of the bottom is 1 in 40, nearly equal to the slope of the chalk itself
at St. Acheul, which is 1 in 33. This river is now dry.

I ask particular attention to the position and level of this dry
valley, which is similar in character to those occurring on all chalk-
downs and plateaux.

The chalk surface at St. Acheul is also hollowed out into a valley
situated north of the Imperial Road, widening out as it approaches
the Somme, after the ordinary manner of valleys.

By the sections through the St.-Acheul pits, we know this valley
did not extend south of the Imperial Road; but the eastern boun-
dary of this small valley, only 400 or 500 yards long, is well seen
at the La Neuville Eastern Bridge, where the chalk is well exposed
in the railway-cutting, at a height of 20 feet above the rails, and
slopes westwards, passing under the rails near the point C in the
map, between the lines of section I K and L M.

The surface of chalk is shown in a very clear section on the
railway here, covered with 20 feet of loess (fig. 11). The chalk
is nowhere naturally exposed. The force of water from St. Acheul
originally hollowed out this small valley in the chalk, which has
been partly filled up with gravel and loess; and the surface-drainage
of St. Acheul flows to the River Somme down this valley, over a bed
of gravel and loess of some thickness.

There is a very small lateral valley in the chalk, running from
St. Acheul into the now dry valley at the western escarpment, also
covered with loess and gravel. The slope of the side of this valley
is as much as 6°.

Crossing over from the east of Amiens to the west, we come to
the section N O P, which gives us a correct view of the surface of
the chalk at Montiers, where fossiliferous gravels were discovered
by Mr. Prestwich. (Plate IV. fig. 7.)

The gradients have been already described. Between N and O
the surface of the chalk is slightly convex; but between O, a point
120 feet above the Somme, and the Somme itself, the surface of the
chalk is concave.

In an elevation of 60 feet, between O and P, the concavity of
the chalk is as much as 20 feet, or one-third of the total height.
It is in this basin of the chalk that the great gravel-beds of Mon-
tiers may be seen, in which 30 feet of gravel and loess is well ex-
posed, south of and close to the Imperial Road. The fossiliferous
gravel extends above the railway; and Mr. Prestwich found shells
in a pit which appears to be about 50 feet above the river at
Montiers.

The chalk is nearly horizontal beneath the rails for a distance of
1077 yards between the line of the section N O P and N Q; at least
it is 15 feet below the rails on the line N O P, and 9 feet below
the rails at N Q (fig. 12, p. 123). As at St. Acheul, the slope of the
surface follows the chalk to some extent, and falls towards the river.
The average gradient is $2\frac{1}{4}°$, or 1 in 43, along the line N Q, against
a gradient of $2\frac{3}{4}°$, or 1 in 33, at St. Acheul, along the line L M; but

the chalk is convex on the average at L M, and concave on the average at N Q. This, however, requires more explanation.

The surface of the chalk between the line of 200 feet and of 120 feet above the sea is convex on the line N O P, at the maximum to the extent of 14 feet out of 86 feet perpendicular height; and we see very little gravel reposing on the convex surface. On the contrary, in L M, between the 200-feet and 135-feet levels, the maximum concavity is 15 feet; and the great mass of the St.-Acheul gravel is deposited in this hollow.

But when we examine the surface of the chalk between O and P, between the 120-feet and 60-feet levels, we find the chalk surface is concave to the extent of a maximum of 29 feet, out of a total of 60 feet; and, singularly enough, this 29 feet is almost exactly the maximum thickness of gravel and loess in the great pit at Montiers, where a section several hundred yards long is exposed.

On the contrary, between the 130-feet and 76-feet levels on the lines L M and I K, where the surface of the chalk is convex, there is no gravel of any importance.

In the section (Plate IV. fig. 1) between L M and I K the chalk is nearly a straight line, falling $2\frac{3}{4}°$ between the 130-feet and 90-feet levels; we have 9 feet of gravel and loess exposed in this favourable position for its accumulation.

When we see the gradual slope of the surface from the point O to the River Somme at P, we are indeed surprised to find the sudden change in gradients in passing southward from O to Renancourt, across the now dry valley leading from Ferrières (passing by Saveuse) to Amiens, a distance of four or five miles. These escarpments commence near Ferrières, and increase as the bottom of the valley falls in a north-easterly direction towards the river Cette. I measured a section near the Ferme de Grâce, where the side of the dry valley slopes at an angle of 20° to the bottom.

These escarpments are better shown in a section taken from the point O, towards Renancourt, and giving gradients from 30° to 50°, representing flood-lines of former periods, but so sharp in definition that they look like the work of the last winter. (Fig. 7.)

Fig. 7.—*Section across the Saveuse valley.*

380 yards broad.   28 yards deep.
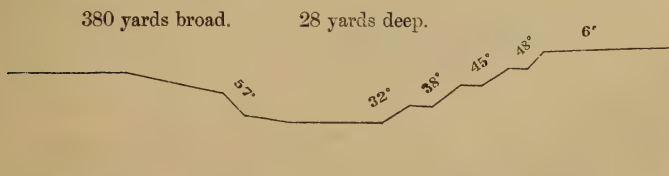
It is obvious that any theory of excavation of the Somme valley, at Amiens, must take into account the condition of the dry Saveuse valley, which is only a type of hundreds of other dry valleys, which formerly were filled with water falling into the Somme and swelling it into a river capable of overflowing St. Acheul.

In the same way no argument can be satisfactorily applied to the formation of the Somme valley, without considering the relation of the chalk-valleys generally, which resemble each other in so many important respects, and are alike in general features as well as in the mineral composition of their strata and their superficial contents.

On some other occasion, after the Society has heard my account of some other valleys, and seen my measured sections, I shall venture to lay before them the views of the formation of the Somme valley which I hold. I shall now only remark that the bottom of the valley of Saveuse opens into the valley of the Cette, between Montiers and Renancourt, at a height of 92 feet above the sea, and is 140 feet high above the sea near the Ferme de Grâce, and 187 feet above the sea near Saveuse, and that there are continuous terraces of loess, varying in form and elevation, sometimes with the configuration of the chalk-valley on which they repose from one end to the other, but evidently the consequence of water filling the Saveuse valley on its passage from Ferrières to Montiers.

2. *The Gravel and Loess.*—From the fine or coarse character of the gravel, and from the thickness of the loess, we may infer some of the physical circumstances which occurred at the period of deposition. The loess is in some places sandy, and in others is a fine loam, but it varies little in coarseness. At the same height above the river I have observed great discrepancies in the thickness of the true loess : thus, at a pit 200 yards east of the line N Q, 15 feet of loess was well exposed in a new pit from which a good quality of brick-earth was being removed and carried a long distance to the brickfields at Montiers; and I was informed there was a depth of 16 feet more before the gravel was reached. There was a gravel-pit on the same level, a little to the west. On the edge of the Saveuse valley, 400 yards south of O, the loess was only from 1 to 2 feet thick. At St. Acheul it was only 5 or 6 feet thick; but there were intermediate beds of marl and sand between the true loess and the true gravel there.

There seems to be a line of thicker brick-earth or loess running south and north between the lines O P and N Q. This would indicate that the water was more tranquil at that point. Such differences in currents are very apparent in rivers at the present time; and the warp of our rivers approaches very nearly to the character of loess. The fossiliferous gravels at St. Acheul extend to a height of 70 feet above the river, or much higher than the corresponding fossiliferous gravels in the valley of the Thames. The shells are found in false-bedded fine sand, and not in clay, at St. Acheul, and in precisely the same condition as at Crayford.

The Cyrena shell-bed at Crayford, however, is only 38 feet above the sea ; but both the St.-Acheul and Crayford gravels extend upwards and join the plateau beds, while they pass downward as far as the river in both cases.

The chalk is capped in some places with Tertiary sands at Crayford; but the gravel lies on the concavities of chalk and sand quite indifferently.

The River Cray falls into the Thames much as the River Arve falls into the Somme. The Crayford gravel is 100 feet thick, and confined to a space between two valleys, the eastern valley occupied by the River Cray, and the other and western a dry valley, like that south-west of St. Acheul.

Bounded by valleys east and west, the Crayford and St.-Acheul gravels lie against escarpments of the chalk parallel to the Rivers Thames and Somme.

I have not presented more than a few varieties of the gravel-sections to be observed in Amiens, for want of room (Plate IV. figs. 12 & 13, and fig. 8 below), and I propose to make some remarks upon the peculiarities of deposition to be observed there at some future time. I will now only observe that the character of the sections, I think, clearly shows us that a large quantity of the gravel material now exposed in the quarries opened for ballast near Amiens had its source in the hills or plateau immediately adjoining and above St. Acheul and Montiers, and was washed into the valley of the Somme in a direction from south to north, and mingled with the materials brought down by the Somme, flowing from east to west.

The quantity of chalk-detritus is about one-eighth of the whole mass of gravel and loess, and makes the Amiens deposit second in importance to the Brighton gravel, as far as the presence of chalk is concerned. The unrolled condition in which the large pieces of chalk in the gravel generally occur proves the local origin of the chalk, and that it has been brought down from the high lands and not thrown up by the river.

We might expect an important difference in mineral character between the gravel and loess at the respective heights of 150 and 75 feet above the sea. I have compared the gravel of St. Acheul, 140 feet above the sea, with that at Montiers, from 70 to 80 feet above the sea, as carefully as I could, in order to find some marked distinctions, but up to the present time without success. I have sketched a piece of gravel at St. Acheul, 140 feet above the sea (Plate IV. fig. 12), and a piece in La Neuville, 105 feet above the sea, and immediately north (fig. 8). There is a great deal of varia-

Fig. 8.—*Section in La Neuville Ballast-pit.   Loess and Gravel.*
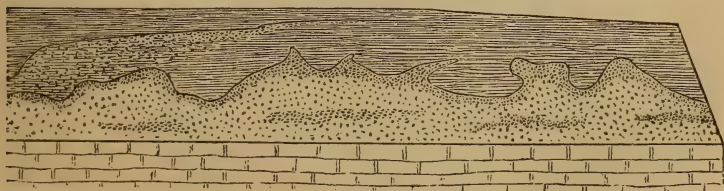
tion between these two sections; but there is still more variety in the gravel-section of a part of St. Acheul, 200 yards to the east, at a height of 145 feet above the sea (Plate IV. fig. 13). Similar species of shells have been discovered and named by Mr. Prestwich and others at Montiers and St. Acheul, at very different levels; but there

are none characteristic of any particular elevation above the river. Bones and flint implements are said to be found throughout the Amiens gravels; but as I have never found any myself, nor seen any found, I cannot speak on this point from observation; and it does not appear that these remains, any more than the shells, would enable us to distinguish any particular level.

The large stones of Grès are abundant in all the quarries. I made notes of the numbers and sizes of all I observed, and found that they are also distributed as much in the gravel above the railway as below it, and range up to 4 feet long. There are as many and as large blocks of Grès in the Montiers northern pits as in those at St. Acheul. I observed one Grès at La Neuville partly covered by loess, the rest of the stone being on gravel; but elsewhere the Grès stones were always in the gravel.

I have mentioned the loess being a very good brick-earth at a point 120 feet above the sea in Montiers. The colour and material of the loess is generally a dull brown, varying in proportions of clay and sand and in the amount of angular flints contained in it through-out the whole area. I have, however, remarked a reddish friable brick-earth on the terraces fringing the Somme at Longueau, ninety feet above the sea. This is probably of the same character as that in the similar terrace at Neuville and Montiers. This brick-earth is very similar to that of the River Lea; indeed at Clapton there is a well-marked terrace of brick-earth bounding the marshes, which are composed of gravel. The Clapton terrace is higher than that of the Somme at Amiens, and reposes on London clay, instead of chalk as at Amiens.

This low escarpment of loess is to be seen for a great many miles eastward along the Somme; and, from the angle at which it faces the river, with its flat top, it so resembles a military earthwork that it is often regarded as artificial. I have measured the escarpment at five or six points; and the angles vary from 20° to 40°, the average being 35° (figs. 9 and 10.)

In the Saveuse valley the angles are also various. I have often remarked similar escarpments in England. I made a note of a

Fig. 9.—*Section near Cagny, in the valley of the Arve.   Loess Terrace just above the level of Marsh.*
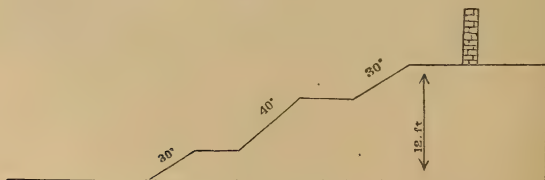
series of terraces, seven in number, one over the other, on the chalk hills, on the north side of the Somme valley, about nine miles from Amiens, on the Paris line; and, indeed, in the space of ten miles you may see twenty small lateral valleys opening into the

Somme, with escarpments as distinct and well marked as those
drawn of the Saveuse valley.

Fig. 10.—*Section three-quarters of a mile south of M. Dailli's house
(valley of the Arve), Loess Terrace.*
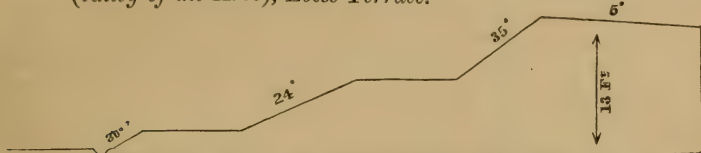
These were steps cut in the brick-earth of the Saveuse valley by
the peasants, to enable them to get up the steep sides; but that
was the only information I was enabled to get as to the structure
of parts of these terraces, except at Longueau, where a pit was open
and good brick-earth visible; so I do not know their relation to the
chalk. At Camilla Lucy House, West Humble, near Dorking, I saw
a terrace cut into, sloping to the valley at 25°. The gravel was 5
feet thick on the face of chalk, and 7 feet thick 30 yards from the
escarpment.

These terraces are of great importance to any one investigating
the geology of the Somme, but are not noticed by any other writer,
as far as I am aware.

V. Conclusion.

What the sections described in this paper plainly tell us is, that
the chalk valley of the Somme was excavated exactly to its present
form prior to the deposition of any of the gravel now lying in it.
Perhaps many layers of gravel may have been deposited and removed
again in this ancient chalk valley before the present gravel was
deposited; but of this we cannot be certain; so that we must take
the first layer of gravel covering the chalk from the higher part of
the section to the lower in the section, as the oldest in the section, and infer that
the remainder of the gravel-series was deposited in regular sequence.
The most delicate shells are fossilized in the river-sand of St. Acheul
and Montiers, just as they have been in that of Crayford and Erith.

This is a proof of the peaceful character of the deposition of
some part of the Amiens beds, just as the large flints and blocks of
Grès, which are so abundant among the gravel, are a proof of the
power of the floods which brought the coarse gravel from the pla-
teau, or down the rivers. If the sections near Amiens show the
valley-gravel continuous from a height of 200 feet, at St. Acheul and
the Ferme de Grâce, to the River Somme (coated over by a nearly
uniform warp of loess), and laid at a low gradient not exactly par-
allel to the surface of the chalk, but rather in its concavities, then
we must necessarily admit that the water of the Somme has at times
flowed over the whole surface in question from top to bottom in one
flood. This is not an exceptional case at all, as I should have
been able to demonstrate, had I been able to bring forward my sec-
tions of other river-gravels this evening. We are all agreed that a
state of meteorological phenomena existed during the glacial period

very different from any now to be met with in these latitudes; there-fore there is no *primâ facie* improbability in supposing a pluvial period even of longer range in time than the glacial epoch.

The existence of such a pluvial period is demonstrated by the size, constitution, and level of the fluviatile gravel and loess depo-sits at Amiens and other well-known localities.   Large rivers cer-tainly existed to a later date than the glacial period, as they formed such large terraces of loess over the glacial gravels.   If we were to judge of the age of these later deposits, such as the loess escarpments at Amiens and Clapton, by their modern appearance and by their being unaltered by weather and not cut into by streams, we should place them almost in the historical period.   The Amiens sections of loess accord with those of the Rhine and other rivers.   The difference between this loess deposit at Amiens and the present warp of the Somme ought to be an index of the rainfall in the pluvial period, when the loess was deposited, as compared with that falling at the present time; and we may look at these gravels and loess beds as registering rain-gauges.

In the same manner, the comparative rainfall at the epoch of the deposition of gravels might be estimated approximately by com-paring the dimensions of the blocks of Grès and large flints moved by fresh water in the gravel-period with the size of the materials moved in the same valleys at the present time.

The existence of a glacial period almost necessitates that of a pluvial period, commencing prior to the glacial, and continuing after it, occupying a region south of that occupied by the ice and snow.

We should have had no cause for surprise if, when the theory of a period of ice and snow in these latitudes was first broached, the probability of a rainy period south of the Thames had been also deduced from a consideration of the effects of so large a mass of ice and snow on the country and atmosphere bordering on the ice-land, but possessing a warmer climate.

We have the evidence in almost all wet valleys of the river merely occupying a small groove cut in the ancient valleys, which valleys I believe were shaped to their present configuration in such a rainy period as I have inferred.   Every wet valley has a number of dry valleys opening into it, which bear the marks of having been shaped by water and continual showers during the pluvial period.

The points of difference between other authors who have written respecting the Somme Valley and myself are as follows:—

In the appendix to Mr. Prestwich's paper in the 'Philosophical Transactions,' M. Pinsard gives the height of the railway at La Neuville as 83 feet above the mean tide at Havre.   In the survey made for me by M. Guillom, Principal Engineer of the Chemin de Fer du Nord, the height is 96 feet. (Mr. Prestwich has marked this same level as 76, in his drawing, plate 10.   Phil. Trans. 1860*.) This is just 13 feet below the real height.   Again, in Mr. Prestwich's

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* This is calculated from the mean tide at St. Valery, which differs 7 feet from that at Havre.

section, page 257, Phil. Trans. 1864, the height of the rails at Montiers is marked 130 feet ; it should be 99 feet, according to M. Guillom.

It is to be regretted that Mr. Prestwich was supplied with incorrect figures of the relative levels of the ground about Amiens, as the introduction of such errors in the section must have materially affected Mr. Prestwich's theoretical views, as he says, "The upper section at Montiers, which I discovered in 1861, was conclusive as to the relative ages of the gravel" (p. 248, Phil. Trans. 1864).

In the plan, Plate v., Phil. Trans. 1864, accompanying Mr. Prestwich's memoir, the bare chalk is shown as invariably separating the upper and lower gravels all the way from Amiens to Abbeville ; but I have never seen a case of the kind.

It must be remembered that so much gravel has been removed during the last four years, that the sections are now much clearer ; and, with the assistance of the accurate measurements of M. Guillom, present examiners have a great advantage over their predecessors, in examining the structure of the gravel near Amiens.

I cannot suppose that Mr. Prestwich would now separate the Montiers gravels, seen in and above the railway-cutting at Montiers, from those in the Great Montiers pit, and into two horizons, as there is only a difference of twenty-two feet between the height of the gravel on the top of the railway-cutting and that in the Imperial road. As nearly the whole space between these two points has now been excavated, the continuity of the gravel is now proved.

When Mr. Prestwich supposed that there was a continuous bare band of chalk separating the gravel in the railway-cutting at Montiers from the gravel near the Imperial road, and that the top of the railway-cutting was (according to the measurement in his section, page 257, Phil. Trans. 1864) sixty feet above the Imperial Road, he very naturally took a different view of the relations of the gravels from what we must take at the present time, with the additional information we possess.

The section on Plate IV., therefore, appears to destroy Mr. Prestwich's argument, on which he has constructed a division of the gravels at St. Acheul and at Montiers into upper valley-gravels and lower valley-gravels, of different ages, and situated on different horizons, separated, as he supposed, by a band of bare chalk from each other,—the upper valley-gravel being supposed to have been deposited before the excavation of the last fifty feet of the Somme valley, which excavation, he considered, preceded the deposition of the gravels near the Imperial road, Montiers.

The character of the surface of the chalk at Montiers has been discussed at full length in this paper, and shown to be concave at the pits ; while it is represented as highly convex at Montiers by Mr. Prestwich and Sir C. Lyell.

In the long section C D (Plate IV. fig. 3), the St.-Acheul gravel, at a height of 140 feet above the sea, is shown to be separated from the loess at Longueau, at a height of ninety feet, by an escarpment of bare chalk. The tramway (Plate IV. fig. 1), passing from the Imperial road to the railway, crosses one of the supposed bands of

chalk marked by Mr. Prestwich. But, instead of chalk, there are nine feet of good gravel and loess exposed in this cutting. The La Neuville ballast-pit, exposing ten feet of gravel and loess, is also on the supposed outcrop of bare chalk (Plate IV. fig. 2; R S on the Plan).

The outline of the sections C D and I K would at first sight seem to confirm the opinion advanced by Mr. Prestwich, that the gravel at the 140-feet level might be of a different age to that 50 feet below it.

The loess, also, at Longueau, at the 90-feet level, near C, can be traced to La Neuville, and then up to the St.-Acheul pits continuously. The railway-cutting in La Neuville for half a mile is in loess, with veins of gravel (fig. 12); and this is seen to be continuous with the St.-Acheul gravel to the north, by a number of old pits, and in the tramway. The surface of the chalk is concave in this part of the La Neuville valley, between R S and I K, so that gravel and loess would be retained on it; while along the lines C D and I K there is a very steep escarpment, on which no gravel would lie. This escarpment would be swept by the stream of the river Arve and the Somme, flowing at its base, when swollen by large floods, such as must have happened in the gravel-period.

The only inference, I believe, that can be fairly drawn from the sections on Plate IV. is, that all the gravel and loess of St. Acheul and La Neuville is of one period, and that it remained spread over the valley of the Somme where the ground was concave enough to retain it. The absence of gravel on the steep escarpments and near the river-channels is a proof of great floods and rapid currents during the Quaternary period.

I saw the railway-cutting at Montiers, soon after Mr. Prestwich's visit; it was sloped and very much in the state it is at present. (Fig. 12.)

By M. Guillom's section the depth of the chalk below the rails has been accurately determined at two points, where the sections N Q and N O P cross the railway (see figs. 8 and 9, Plate IV.). In fig. 8, M. Guillom found the chalk 8 feet below the rails; in fig. 9, 14 feet below the rails. Mr. Prestwich has represented this railway-cutting as on one of his bands of chalk, dividing the valley-gravels into two horizons; and, in consequence, I had the section N O P taken, as nearly as I could, on the same line as Mr. Prestwich, because I had always remarked gravel in the Montiers railway-cutting, and not chalk. I also give a section along this railway (see fig. 12, page 123). By the French survey the chalk is 14 feet below the rails. In Mr. Prestwich's section of the same place, it is 20 feet above the rails. This difference of 34 feet added to the error in the height of rails, before mentioned, of 31 feet, makes a total difference of 65 feet in the height of the chalk between Mr. Prestwich and M. Guillom, supposing I am correct in placing Mr. Prestwich's section on the line N O P.

Mr. Prestwich has recently informed me that he considers his section was intermediate between the lines N O P and N Q. As the railway-cutting ceases at the ballast-pit (fig. 12), and there is an em-
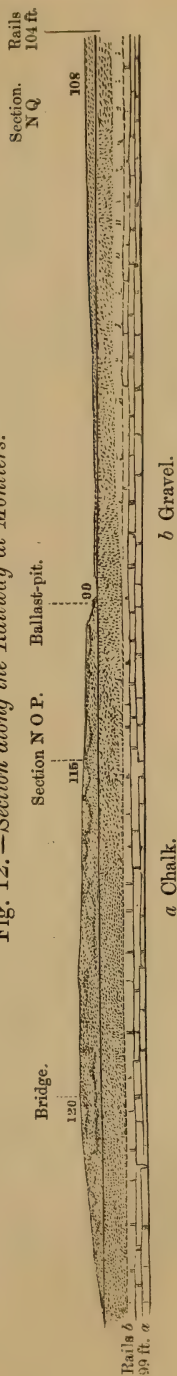
Fig. 11.—*Section along the Railway from Longueau, through La Neuville to the Station works.*
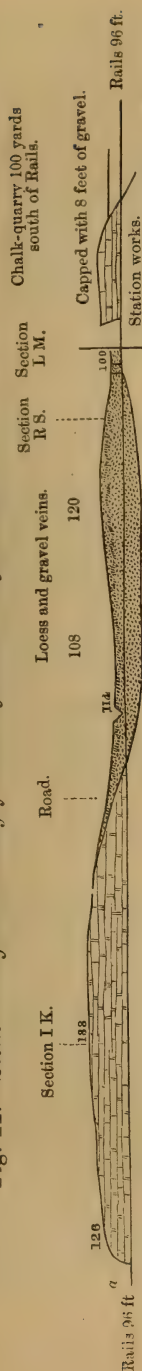
Figs. 11 and 12 are only approximative, as this was not included in the part of Amiens kindly surveyed by M. Guillom.

Fig. 12.—*Section along the Railway at Montiers.*

But as the Quaternary beds below the escarpment at Longueau and La Neuville consist only of loess with thin veins of gravel and without fossils, these sections do not support the view taken by Mr. Prestwich that there is a low-level fossiliferous gravel completely separated by an escarpment of chalk from the St.-Acheul gravel.

The veins of gravel in La Neuville thicken towards the west, and the gravel in the La Neuville ballast-pit may continue beneath the Stationworks; if so, this gravel is part of the stream of gravel which has descended from St. Acheul down the La Neuville valley into the Somme, and can be traced from St. Acheul continuously to the La Neuville ballast-pit, and passes (in thickness unknown) under the rails, as represented in the Section, fig. 11. The La Neuville deposits are not really separated from St. Acheul by a bare band of chalk, but they wrap round the base of the high stratum of chalk which is seen in L M and I K, and which forms the east and west side of the La Neuville valley.

bankment to the west of that point for some distance, it is difficult to place Mr. Prestwich's section at any other point than where I supposed it was taken, on account of the configuration of the ground. Whether there was chalk, or not, at any one point, is quite immaterial to my argument. I do not find the Montiers section at all as represented by Mr. Prestwich and Sir C. Lyell. (See fig. 12, p. 123.)

The Montiers section appears to be the one adopted as a type of the Somme district, first by Mr. Prestwich and afterwards by Sir C. Lyell. Both authors represent, in several sections of the Somme, a great extent of chalk, separating highly inclined beds of gravel, which they have distinguished in age by its position above or below this outcrop of chalk, as upper- and lower-, or high- and low-level gravels. The sections which I place before the Society appear to me, on the contrary, to show that this distinction is not a real one, but that the deposit of gravel is one and continuous, deposited in concavities of an ancient chalk valley, and is not highly inclined as represented in the 'Antiquity of Man' and the 'Philosophical Transactions.'

In page 264, Phil. Trans. 1864, Mr. Prestwich gives a theoretical account of the view he takes of the deposition of the gravels. Part of the upper-level gravels are represented as remaining untouched, while the valley is cut down 50 feet, and a newer set of gravels deposited at lower levels ; my sections show that there is no evidence of any such action.

The same views are extended by Mr. Prestwich to the loess deposits ; the loess of St. Acheul is considered a much older deposit than the loess at Montiers.

Mr. Prestwich lays great stress, in his paper in the Society's Journal, p. 500, on the valley being too large to admit of the possibility of its being filled with water up to a height of 100 feet above the present water-level.

I have already submitted the argument that we ought to judge of the height of a flood by means of the *débris* it has left, and not by any theoretical notions of our own.

In 1866, twenty inches of rain fell in Scinde in twenty-four hours, in a flat country intersected by rivers. Nine girders, weighing nearly eighty tons each, were washed off the piers by the Mulleer River from the Railway Bridge, situated sixteen miles above Kurrachee (fig. 13). This bridge consisted of eighteen girders (see Plate IV. fig. 10.) They were not box girders, but made of wrought iron on Warren's system. The bottoms of these girders were sixty-five feet above high-water mark, spring tides, Kurrachee Harbour, and seventy-four feet above low-water spring tides. They fell in the course of six hours ; and one girder of the weight of eighty tons was carried two miles down the river, and nearly buried in sand*. The section of the river bridge is represented (Plate IV. fig. 10). The fall of the Mulleer River only averaged ten feet per mile for fifteen miles

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* Mr. John Brunton, F.G.S., Chief Engineer of the Scinde Railway, was present at the Meeting, and confirmed this statement, which he had previously given me.

above the bridge; and as rain rarely falls, there is generally less than a foot of water in the river-bed. This bed was nearly dry the

Fig. 13.—*Map of the district near Kurrachee.*

day after, as well as the day before this excessive rainfall. Other instances of the same kind have been reported from India. The river first banked up wood and grass against the bridge, and then threw the girders over. The weight of these girders moved in a river-bed of the dimensions given (Plate IV. fig. 11) * is an index of the rainfall in Scinde, just as the fluviatile beds at Amiens are an index of the current of the Somme, of its flood-level, and the force of its stream. We cannot determine the rainfall at Amiens in the Quaternary Period except by its results in the form of gravel - deposits ; and these appear to give as good indications as the fall of the Mulleer-Bridge girders does of the flood in that river.

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2. *The* GRAPTOLITES *of the* SKIDDAW SERIES. By HENRY ALLEYNE NICHOLSON, D.Sc., M.B., F.G.S. &c.

(Read December 4, 1867†.)

[PLATES V. & VI.]

CONTENTS.

I. Introduction.
II. Description of the Genera and Species of Graptolites.
III. Appendix, and List of the Species.

I. INTRODUCTION.

THE Skiddaw Slates form the base of the great Silurian series of the north of England, and comprise a group of rocks entirely without admixture with interstratified igneous matter, attaining a thickness of about 7000 feet, as calculated by Prof. Harkness. Lithologically the series consists essentially of dark indurated shales, with a distinct cleavage, " having intercalated through them coarser strata, almost devoid of cleavage, possessing a flaggy nature, and affording fossils " ‡. No distinct subdivisions can be drawn either on strati-

* Figs. 10 and 11, Plate IV. are from drawings supplied by Mr. W. A. Brunton, C.E.
† For the other communications read at this Evening-meeting see p. 8.
‡ Quart. Journ. Geol. Soc. vol. xix. p. 113.

graphical or on palæontological grounds, the beds being everywhere
conformable and of nearly similar lithological aspect, while most of
the characteristic fossils are found throughout.   The upper beds of
the series, however, are more shaly, softer, and darker in colour than
the lower, whilst the peculiar genera *Dichograpsus* and *Tetragrapsus*
do not seem to be represented in them, and there is a slight admix-
ture of Upper-Llandeilo types.

When the Skiddaw Slates were first studied by Professor Sedgwick,
two Graptolites, and some obscure tracks (the so-called " *fucoids* ")
constituted all their known organic remains ; and the group was
therefore considered by him the probable equivalent of the Long-
mynd or Cambrian Formation (see Synopsis Brit. Pal. Foss. Intro-
duction, p. xxi).   Since then, however, and mainly by the researches
of Prof. Harkness, we have become acquainted with a large, if not
very varied, fauna from the Slates, and we are thereby enabled to
refer the entire group with certainty to the age of the Lower
Llandeilo rocks.   At home the Skiddaw Slates have no positive
equivalent, but abroad they find an unquestionable representative in
the Quebec group of Canada.

The fossils of the Skiddaw series include a large and remarkable
group of Graptolites, and a few remains of animals higher in the scale
of creation.   These latter comprise a common Phyllopod crustacean, the
Caryocaris Wrightii, a new *Phacops* which Mr. Salter has done me
the honour to name *P. Nicholsoni*, *Agnostus Morei*, *Æglina binodosa*,
and fragments apparently belonging to a large *Ogygia*.   A *Discina*
is mentioned (Cat. Fossils in the Jermyn Street Museum) as occur-
ring at Skiddaw ; and I have likewise found a small *Lingula*, of
not uncommon occurrence, considered by Mr. Davidson to be
L. brevis.   Lastly, there occur numerous Annelid-burrows, and
worm-tracks, to which may be referred the *Palæochorda major*,
P. minor, and *Chondrites acutangulus* of M‘Coy, all properly belonging
to the genus *Helminthites* of Salter (Mem. Geol. Survey, vol. iii.).
The great bulk, however, of the organic remains of the Skiddaw
Slates consists of Graptolites ; and the remarkable point about these
is their close resemblance to, and in many cases specific identity
with, the Graptolites of the Quebec group of America, which have been
so ably described, and so beautifully illustrated by Prof. James Hall
(Geol. Survey of Canada, Decade ii.).   The Skiddaw Graptolites have
been briefly noticed by Mr. Salter (Quart. Journ. Geol. Soc. vol. xix.
p. 185), who gives a list of fourteen species as then known to him.
Some of these I have found it necessary to omit ; but the materials now
in my hands enable me to raise the total number of species to twenty,
belonging to six genera, and forming a peculiar and unique assem-
blage.   As regards their distribution they may be divided into three
groups.   The first of these comprises forms which are entirely con-
fined, as far as we yet know, to this particular horizon, and which
are referable to the genera *Dichograpsus*, *Tetragrapsus*, and *Phyl-
lograpsus*.   In America various other genera belong to this section,
which have not hitherto been found in Britain.   The second division
comprises species belonging to the cosmopolitan genera *Diplo-*

grapsus and *Didymograpsus*, which are not known to transgress the limits of the Lower Llandeilo rocks. Some of these, as *Diplograpsus antennarius*, *Didymograpsus V-fractus*, &c., are exclusively confined to the Skiddaw and Quebec groups; whilst others, as *Didymograpsus geminus* and *D. hirundo*, occur commonly in other parts of the Lower Llandeilo series, and in other localities. In the third section neither are the genera peculiar, nor are the species exclusively of Lower-Llandeilo age; but this division includes forms (such as *Diplograpsus teretiusculus*, His.) which are of common occurrence in the Upper Llandeilo rocks, and which seem to be exclusively limited to the Upper portion of the Skiddaw series.

In examining the species proper to the Slates, I shall briefly consider the generic forms, with especial reference to those which are peculiar to this horizon, and characteristic of it, since there exists considerable divergence of opinion as to their classification and nomenclature.

II. Description of the Genera and Species of Graptolites.

Genus Dichograpsus, Salter.

This genus was proposed by Mr. Salter to include certain complex Graptolites of the Skiddaw and Quebec series, the essential part of the original definition being the possession of a "frond repeatedly dichotomous from a short basal stipe into 8, 16, 24, or more branches, each with a single row of cells," the lower part of the stipes being enveloped by a corneous cup (see Geologist, vol. i. p. 74, and Quart. Journ. Geol. Soc. vol. xix. p. 139). Prof. Hall, however, in his work on the Graptolites of the Quebec group, rejected the genus entirely, and placed all the species belonging both to *Dichograpsus* and to *Tetragrapsus* in his utterly unwieldy genus *Graptolithus*. The more complete materials now at our command have no doubt shown that Mr. Salter was in error when he made the dichotomous division, the even number of the branches, or the possession of a corneous disk an essential point of the diagnosis; for all these characters are absent in some *Dichograpsi*: still the genus appears to be both natural and convenient, and there seems to be no adequate reason for its rejection. In point of fact, the reason which induced Hall to include various branching forms in the genus *Graptolithus* was the mistaken belief that the simple monoprionidian Graptolites, such as *G. Sedgwickii*, *G. sagittarius*, *G. priodon*, &c., had no real existence in nature, but that they were always fragments of compound species. The phenomena, however, observed in Britain and on the Continent render it unquestionable that such simple forms do absolutely exist; and to these, therefore, the genus *Graptolithus* should be in future restricted. At the same time it must be freely admitted that in the absence of perfect specimens it is often extremely difficult to settle the generic position of a species, and that in some cases it may even be impossible.

The characters of the genus *Dichograpsus*, as defined by our present

knowledge, are the possession of a frond composed of a variable number (always more than four) of simple stipes, united centrally at the base by a non-celluliferous stem or "funicle." The primary subdivisions of the funicle are always, and the secondary subdivisions generally, non-celluliferous (*Dichograpsus Milesi*, Hall, sp., being the only form in which the reverse is certainly the case). The stipes are monoprionidian, and are given off from the funicle in a radiating manner. The divisions of the funicle are sometimes, but not always, enveloped by a corneous disk.

In the typical species of the genus, namely *D. Logani*, Hall, sp., and *D. octobrachiatus*, Hall, sp., the celluliferous stipes are never divided, but the frond becomes compound simply by the branching of the funicle; in these also the central disk is usually present, though not uniformly so. In another group, of almost subgeneric value, comprising *D. flexilis*, Hall, *D. rigidus*, Hall, *D. multiplex*, Nich., and other species, the celluliferous branches are themselves subdivided, so that the frond becomes doubly compound, whilst the central disk appears to have been constantly absent. The fact that the central disk is present in some *Dichograpsi* and wanting in others, not being uniformly present in different individuals of the same species even, whilst it occurs also in some species of *Tetragrapsus*, is sufficient to show that it cannot be considered a generic character. It appears to be composed of two corneous laminæ, united at their edges, but enclosing a central cavity; and it is believed by Prof. Huxley and Mr. Salter to be most closely analogous to the basal plate of *Defrancia*, a Polyzoon. I am, however, inclined to believe that a much more feasible homologue is to be found in the "float" or "pneumatophore" of the *Physophoridæ*, an order of the Oceanic Hydrozoa. This view is rendered more probable by the occurrence of a somewhat similar disk in some specimens of *Diplograpsus bicornis*, Hall, as originally pointed out by Hall; and I have observed the same phenomenon in a species of *Diplograpsus* allied to *D. palmeus*, Barr., from the Graptolitiferous rocks of Dumfriesshire. If, however, this conjecture be correct, we should have to believe that this organ was developed only at certain stages of growth, in certain individuals of the species, and probably for certain definite purposes. Indeed, in *Diplograpsus bicornis*, Hall, an unbroken series of gradations can be traced, from those individuals in which the disk is wholly wanting, up to others, in which it is largely developed.

The species of *Dichograpsus* known to me as occurring in the Skiddaw Slates are three in number, namely *D. Logani*, Hall, *D. octobrachiatus*, Hall (=*D. Sedgwickii*, Salt.), and *D. multiplex*, Nich., of which the last is new, whilst the other two are well-known Canadian forms.

1. DICHOGRAPSUS LOGANI, Hall, sp.

  Graptolithus Logani, Hall (Pal. N. York, vol. iii., and Graptolites of the Quebec group, p. 100, pl. ix.).

This is a very beautiful and characteristic Canadian species, of

which I was fortunate enough to discover the only specimen hitherto found, at Outerside near Keswick. It is recognized at once by the numerous simple stipes springing from the central branched funicle, but not themselves subdividing. The mode of division of the funicle, and consequently the number of the stipes, is not constant; but the branches are usually symmetrical in the same individual, varying in number from 18 to 25, but not exceeding the former number in the specimen before me. The subdivisions of the funicle are usually embraced by a corneous disk; but in many specimens this is either not developed, or it has been lost previous to fossilization. The cellules vary in number from 22 to 26 in the space of an inch; the denticles are acute and angular, with their upper margins (the cell-apertures) nearly at right angles with the axis, and not at all unlike the adult form of *G. sagittarius*, Linn. The breadth of the stipes is not great, the maximum in my specimen being about $\frac{1}{16}$ of an inch.

Loc. Outerside, near Keswick.

2. DICHOGRAPSUS OCTOBRACHIATUS, Hall, sp. Pl. V. figs. 1, 2.

> *Graptolithus octobrachiatus*, Hall (Geol. Survey of Canada, Report for 1857: also Graptolites of the Quebec group, p. 96, pls. 7 & 8).
>
> *Dichograpsus Sedgwickii*, Salter (Quart. Journ. Geol. Soc. vol. xix. p. 138).
>
> *Dichograpsus aranea*, Salt.

This species is of very rare occurrence in the Slates; and I am unable to find any undoubted specimen of it in the collection of either Prof. Harkness or myself. It was first noticed in Britain by Mr. Salter[*], who named it *D. Sedgwickii*; but Hall's name (with the date of 1857) appears to have the priority, and I have therefore adopted it. The frond consists of eight simple stipes, arising from a short funicle, which is furnished with a median radicle. The funicle divides dichotomously, so as to give rise to eight short radiating non-celluliferous branches, which are prolonged into the same number of monoprionidian stipes. Unlike the preceding species, the number of stipes appears to be constant, or nearly so, and can therefore be used as a specific character. There is almost invariably a central disk surrounding the divisions of the funicle (Pl. V. fig. 1); but it may in some cases be absent, as in the specimen figured by Mr. Salter. The cellules are about 20 in the space of an inch; the denticles are well marked; and the separated stipes probably constitute one of the forms upon which the *Graptolites latus* of M'Coy was founded (Pl. V. fig. 2).

Loc. Braithwaite, near Keswick; Mire House, near Skiddaw(?).

3. DICHOGRAPSUS MULTIPLEX, Nicholson. Pl. VI. figs. 1-3.

I have referred this unique and extraordinary Graptolite to the

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[*] In the Geologist, vol. i. 1861, I believe, but I am unable to refer to a copy of this work.

genus *Dichograpsus*, to which it appears properly to belong. Owing, however, to the bad preservation of this as of most of the Skiddaw Graptolites, hardly any distinctions of any value can be drawn from the minuter characters of the frond; and the generic position must be mainly determined by the mode of branching. The specimen before me, the only one hitherto discovered, is from the collection of Prof. Harkness, and contains the remains of two individuals. The perfect frond consists of four compound branched stipes, springing from a central funicle; so that it might be considered a compound *Tetragrapsus*. The length of this central portion, or "vinculum," is from $\frac{1}{10}$ to $\frac{3}{10}$ of an inch; and it appears to be really devoid of cellules, thus constituting a true "funicle." It divides at either extremity into two branches; but I am unable to make out whether these bear cellules or not, and am therefore uncertain where the funicle ends and the celluliferous stipes begin. Each of these four divisions (which are probably parts of the funicle) then divides into two, the branches thus produced repeatedly subdividing in a similar dichotomous manner, at intervals of from $\frac{1}{2}$ to 1 inch, and at angles of from 50° to 60°. The single stipes are monoprionidian, about $\frac{1}{20}$ of an inch in breadth, without any well-marked axis, but with a conspicuous common canal. The cellules are very badly preserved, there being apparently about 16 in the space of an inch; the denticles are prominent and angular, but are too imperfectly retained for further particularization. In one individual, one of the main stipes, with its subdivisions, attains a length of 7 inches, without showing any signs of a termination; so that the breadth of the entire frond must have been more than 14 inches. *Dichograpsus multiplex*, from its mode of division, is obviously and closely related to that group of the Quebec *Dichograpsi* which contains *Graptolithus flexilis*, *G. rigidus*, and *G. abnormis* of Hall; and as these are devoid of any central disk, it is probable that this species also wanted that appendage. It differs from the above Canadian species in its much greater size, in its more regular dichotomous division, and in the nearer approach apparently made by the cellules to the central portion of the frond.

Loc. Near Peelwyke, Bassenthwaite.

Genus TETRAGRAPSUS, Salter.

Like the last, this genus was founded by Mr. Salter, but was subsequently rejected by Prof. Hall, chiefly upon the ground of not being readily applicable to any but perfect specimens. The remarks, however, which I have already made as to the expediency of retaining the genus *Dichograpsus* apply with equal, if not with greater, force to *Tetragrapsus*, for which Mr. Salter's definition, with some alteration, is quite sufficient. The essential characters of the genus consist in the possession of a frond, which is composed of four monoprionidian simple stipes, arising from a central non-celluliferous funicle, which bifurcates at both ends. The celluliferous branches do not subdivide; and there may be a central disk or not. Three

species of *Tetragrapsus* occur in the Slates, all well-known Canadian forms, viz. *T. bryonoides*, Hall, *T. quadribrachiatus*, Hall, and *T. Headi*, Hall; but several other species are found in the Quebec group, and may subsequently be recognized in Britain.

4. TETRAGRAPSUS HEADI, Hall.

> *Graptolithus Headi*, Hall (Grapt. Quebec group, p. 94, pl. 5. figs. 11, 12, pl. 6. fig. 8).

A single specimen, apparently belonging to this species, has been found at Barff, and is now in the possession of Prof. Harkness. As the cellules are not exhibited, it is somewhat uncertain whether the form is *T. Headi*, Hall, or *T. crucifer*, Hall; but the shape of the disk more closely resembles that of a small specimen of the former. The frond consists of four stipes arising from a short funicle, the divisions of which are embraced by a corneous disk. The diameter of the disk is about $\frac{3}{10}$ of an inch from side to side; and its form is four-sided, oblong, or somewhat diamond-shaped, owing to its being prolonged for a short distance along the stipes. The stipes are narrow at their origin, but widen out to about $\frac{1}{15}$ of an inch in breadth. The cellules are not displayed at all; but according to Hall they are about 24 in an inch, elongate, and with submucronate denticles.

This unique specimen is the only one yet found in the Skiddaw Slates in which the central disk is retained.

Loc. Barff, near Keswick.

5. TETRAGRAPSUS QUADRIBRACHIATUS, Hall, sp.

> *Tetragrapus crucialis*, Salt. (Quart. Journ. Soc. vol. xix. p. 138).
> *Graptolithus quadribrachiatus* Hall (Grapt. Quebec group, p. 91, pl. 5. figs. 1–5, pl. 6. figs. 5, 6).

This rare species would be more appropriately designated by the specific name of " *crucialis*" than by that of " *quadribrachiatus*;" but the date of the latter is earlier. The frond consists of four simple monoprionidian stipes, given off by a funicle of variable length, two from each extremity. The stipes diverge widely from their origin, but are symmetrical, unless distorted by pressure; and, when well preserved, the stipes arising from opposite ends of the funicle, and from its opposite sides, are parallel with one another, so as to form a figure like the letter X. The stipes are narrow at their origin, never attaining a great width; and the cellules are from 22 to 24 in an inch. The denticles are acute, but are not produced or mucronate as in *T. bryonoides*, Hall; and no disk has ever been discovered to be present in this species.

Loc. Outerside, near Keswick.

6. TETRAGRAPSUS BRYONOIDES, Hall, sp.

> *Graptolithus bryonoides*, Hall. (Grapt. Quebec group, p. 84, pl. 4. figs. 1–11).
> *Didymograpsus caduceus*, Salt. (Quart. Journ. Geol. Soc. vol. xix. p. 137, fig. 13 *a b*).

> *Graptolites latus,* M'Coy (in part) (Quart. Journ. Geol. Soc. vol. iv.).

This is by far the commonest species of *Tetragrapsus* in the Skiddaw Slates, and is certainly identical with the Canadian form. All the specimens also of *Didymograpsus caduceus,* Salt., which I have seen from the Skiddaw Slates are likewise referable to this species; and it is further one of the commonest sources of the *Graptolites latus* of M'Coy. The frond consists of four simple stipes, which spring from a short central funicle, and are almost always characteristically reflexed. The stipes are narrow at their origin, but rapidly expand, some to a width of $\frac{1}{5}$ of an inch, again contracting towards their distal extremities. The cellules are from 20 to 24 in the space of an inch, the denticles pointed, and the lower margin of the cell-aperture strongly produced, and almost mucronate, so as to render the outline of the cell-mouth curved. The four stipes are seldom all visible at the same time in any single specimen, one pair being almost always better exhibited than the other; but great variations in this respect exist in different individuals.

Loc. Barff, Outerside, Frozzengill.

Genus PHYLLOGRAPSUS, Hall.

In this genus, according to Hall, the frond consists of "foliiform stipes, which are celluliferous upon the two opposite sides, the margins having a mucronate extension from each cellule." *Phyllograpsus* differs from *Diplograpsus* in the fact that in the latter the frond consists of two simple stipes united by their axes, whilst in the former the frond is comprised of four such stipes united back to back by their solid axes. It is possible, as conjectured by Hall, that *Phyllograpsus* was really doubly compound, many fronds being united to one another at their proximal extremities; but I have met with no specimens which would countenance this view. It is somewhat curious that, of all the genera which are exclusively confined to the Skiddaw series, this is the only one which is known to occur in the upper beds of the group.

7. PHYLLOGRAPSUS ANGUSTIFOLIUS, Hall. (Grapt. Quebec group, p. 125, pl. 16. figs. 17–21.)

In this species the fronds are "elongato-elliptical, or elongato-lanceolate," the widest portion being a little above the base. The ordinary length of the frond is $1\frac{1}{4}$ inch; but I have found specimens which reach a length of nearly 2 inches, being $\frac{1}{4}$ of an inch in excess of the longest observed by Hall. The cellules in my specimens are about 30 in the space of an inch (according to Hall, 24), slightly curved, wider at the aperture than internally, the lower margin at the cell-mouth being prolonged into a strong triangular mucro, which is usually somewhat deflexed. There are indications of a central axis; but these are not well marked. This beautiful species is distributed throughout the entire Skiddaw series;

and I have obtained excellent specimens, *in situ*, from some of the highest beds at Ellergill, near Millburn.

Loc. Barff; Outerside; Whiteside, near Crummock; Skiddaw Longside; Ellergill, in Westmoreland.

8. PHYLLOGRAPSUS TYPUS, Hall. Pl. V. fig. 16. (Grapt. Quebec group, p. 119, pl. 15. figs. 1–12.)

This form differs from the above chiefly in the shape of the frond, which is "elongato-ovate or lanceolate, broad-oval or obovate," and likewise in the fact that the apertures of a third row of cellules are always exhibited. The shape and size of the frond, however, are very variable, and too much stress should not be laid upon this character alone. The cellules are about 24 in an inch, the apertures being mucronate, though the mucrones are not so pronounced as in *P. angustifolius*.

Loc. Barff, near Keswick; and Skiddaw Longside.

Genus DIDYMOGRAPSUS, McCoy.

This genus contains those Graptolites in which the frond consists of two simple monoprionidian stipes, diverging from a mucronate "initial point" or "radicle." The radicle is occasionally rudimentary, as in *D. sextans*, Hall, and *D. bifidus*, Hall (in some cases), or is even apparently absent, as in most specimens of *D. anceps*, Nich. The genus *Didymograpsus*, beyond all doubt, includes a series of perfect and unbroken forms, which never, at any time of their existence, constituted factors of compound organisms; though Hall adopts this latter view, and includes the whole group in his genus *Graptolithus*. It cannot, however, be questioned that such compound forms would have been discovered, had they really existed, amongst the thousands of specimens which have been exhumed from the Silurian rocks of Scotland and Wales; and the absence of any traces of such is ample proof that Hall's conjecture is without sufficient foundation.

Seven species of *Didymograpsus* are known to me as occurring in the Skiddaw Slates, of which three are new to Britain. Of the entire number, three are confined to this horizon, viz. *D. V.-fractus*, Salt., *D. nitidus*, Hall, and *D. bifidus*, Hall; two are well-known Lower-Llandeilo forms, viz. *D. geminus*, His., and *D. patulus*, Hall (= *D. hirundo*, Salt.); whilst two are common to the Upper Llandeilo and Caradoc rocks, viz. *D. serratulus*, Hall, and *D. sextans*, Hall.

9. DIDYMOGRAPSUS CADUCEUS, Salter.

This was originally described by Mr. Salter, from Canadian specimens, as a distinct species (Quart. Journ. Geol. Soc. vol. ix. p. 87), and was afterwards noticed by him from the Skiddaw Slates (*ibid.* vol. xix. p. 138). It was, however, subsequently rejected by Hall, on the ground that the species had been founded on specimens of *Tetragrapsus bryonoides*, Hall, in which two only of the stipes

were visible in full, whilst the apparent radicle was consti-
tuted by a small portion of a third stipe. Whether this explana-
tion applies to the specimens originally described by Mr. Salter, I
do not, of course, pretend to say, though the probabilities are in its
favour. Certainly, in a large series of specimens from the Skiddaw
Slates, I have been able to find none in which it would not account
for the phenomena observed. Whilst it is possible, therefore, that
there may really exist a distinct species with the characters of *D.
caduceus*, Salt., it certainly appears not to occur in the Skiddaw
Slates, since all specimens which could be referred to this species,
when well preserved, show traces of a third, and even sometimes of
a fourth, stipe.

10. DIDYMOGRAPSUS V-FRACTUS, Salt.   (Quart. Journ. Geol. Soc.
    vol. xix. p. 137, f. 13 *e*.)

This rare and elegant species is characterized by the fact that
the stipes, after proceeding upwards from the short radicle, bend
abruptly outwards, so as to enclose a much more open angle than
the primary angle of divergence. In all other particulars it is
almost, if not quite, identical with *D. patulus*, Hall (= *D. hirundo*,
Salt.), of which it may possibly be a variety. The cellules are on
the upper or inner side of the frond, *i. e.* on the side remote from
the radicle, and appear to resemble in shape those common to the
majority of the Skiddaw Graptolites, being long, narrow, and pro-
vided with a strong submucronate extension of the proximal lip of
the cell-aperture. The species is said by Mr. Salter to be closely
allied to *D. Pantoni*, M'Coy, from the Graptolitiferous rocks of Vic-
toria.

11. DIDYMOGRAPSUS SEXTANS, Hall.   Pal. New York, vol. i. p. 273,
    pl. 74. fig. 3.

D. sextans is given by Mr. Salter in his list of Graptolites from the
Skiddaw Slates; but I have never seen any specimen of it from this
horizon. It is somewhat peculiar among the *Didymograpsi*, from
the fact that the cellules are placed on the lower or outer side of
the frond, *i. e.* on the same side as the radicle. It occurs in the
Utica Slate in America (Caradoc), and in great abundance in cer-
tain beds in Dumfriesshire (Upper Llandeilo), and it is too well
known to need description.
    Loc. Braithwaite Brow.

12. DIDYMOGRAPSUS GEMINUS, Hisinger (Leth. Suecica, Supp. ii.).
    Pl. V. figs. 8–10.

This well-known Swedish species occurs very plentifully in the
Skiddaw Slates, though seldom well preserved. The form usually
figured as *D. geminus* (see 'Siluria' Fossils 8. fig. 8, and Lyell's
'Elements,' p. 563, fig. 656) is in reality *D. patulus*, Hall (= *D. hi-
rundo*, Salt.). In the true species the frond consists of two small
stipes arising from a long and slender radicle, at first curving out-
wards, and then running more or less nearly parallel with one

another for a distance of $\frac{1}{4}$ to $\frac{1}{2}$ an inch. The stipes do not, as a rule, diverge at an angle as large as in the specimen figured by Mr. Salter (Mem. Geol. Survey, vol. iii. p. 331, pl. ii. B. fig. 8), whilst their length may be more than twice as great. The cellules are on the upperside of the frond, or on the side remote from the radicle, but are either not shown at all, or are extremely badly preserved ; the denticles are angular, and the cell-mouths at right angles to the axes. Curiously enough, *D. geminus* does not appear to occur at all in the Quebec group, though it is such a characteristic Lower-Llandeilo species in Europe.

Loc. Outerside ; Barff ; Bannerdale Fell, near Mungrisedale.

13. DIDYMOGRAPSUS PATULUS, Hall, sp.

 Graptolithus patulus, Hall (Grapt. Quebec Group, p. 71, pl. 1. figs. 10–15).

 Didymograpsus hirundo, Salt. (Quart. Journ. Geol. Soc. vol. xix. p. 137, fig. 13 *f,* and Mem. Geol. Survey, vol. iii. pl. 2. B. fig. 6).

I am unable to discover any important appreciable difference between the species described under the above names, and am therefore inclined to believe that they are identical, or are, at most, varieties of the same. The former name appears, as far as I can make out, to have been the first published (Geol. Survey of Canada, Report for 1857, p. 131) ; and in this case it must be retained, though the other has secured a more general currency*. The only distinction between the two seems to be that in *D. hirundo,* Salt., as ordinarily figured, the stipes are not so long as in *D. patulus,* Hall ; but this is obviously a trivial distinction, and is simply due to the fact that the great majority of specimens are broken.

The stipes in both *D. patulus,* Hall, and *D. hirundo,* Salt., diverge at an angle of 180° from a small radicle, being at first narrow, but widening out till a breadth of $\frac{1}{10}$ of an inch may be attained. The length of the stipes is often great, being as much as $2\frac{1}{2}$ inches in a specimen in my possession from the Skiddaw Slates. The cellules are situated on the upperside of the frond, narrow, and in number from 30 to 34 in the space of an inch in all our British specimens (according to Hall the cellules are from 24 to 26 in an inch ; but I do not think this difference is of specific importance). The denticles are well marked, their tips being produced and almost mucronate.

Loc. Eggbeck, near Ulleswater ; Outerside, near Keswick.

14. DIDYMOGRAPSUS NITIDUS, Hall, sp.

 Graptolithus nitidus, Hall (Grapt. Quebec Group, p. 69, pl. 1. figs. 1–9).

 Also figured but not described by Mr. Salter in the Quart. Journ. Geol. Soc. vol. xix. p. 137. fig. 13 *d.*

This very pretty species is closely allied to the former, though

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* *D. hirundo,* Salt. appears to have been only a MS. species in 1861 (Quart. Journ. Geol. Soc. vol. xix. p. 138).

very much more diminutive.   As it occurs in the Skiddaw Slates, it
is identical with what Hall has figured as the young form of *D. nitidus*
(*Op. cit.* pl. 1. fig. 1); but this should probably be considered a
distinct variety, since none of our English specimens appear to agree
exactly with the adult *D. nitidus* figured by Hall.

The frond consists of two stipes, which diverge from a small
pointed radicle, and include between them an angle of 150° to 175°.
Hall gives the latter as the average; but in our specimens it is often
as low as above stated; and it is better to consider the angle of di-
vergence variable than to found a distinct species upon this character
alone.   The stipes vary in length from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch, very narrow
at their commencement, but widening out until a breadth of $\frac{1}{20}$ to $\frac{1}{15}$
of an inch is attained.   The cellules are from 32 to 34 in an inch;
the denticles are well marked and angular, but not produced or
mucronate, the cell-mouths being at more than right angles to the
axis.

Loc. Common and very well preserved at Barff, near Keswick.

15. DIDYMOGRAPSUS BIFIDUS, Hall, sp.
      Graptolithus bifidus, Hall (Grapt. Quebec Group, p. 73, pl. 1.
      figs. 16–18, pl. 3. figs. 9, 10).

This species is a Quebec form, which I have found in both the
upper and lower beds of the Skiddaw Slates, especially in the former,
though it is by no means of common occurrence.   It approaches
closely to *D. Murchisoni*, Beck; but it seems to be separated from
the latter by sufficiently good characters.   Thus in *Didymograpsus
Murchisoni* the base is furnished with a long radicle, and the cel-
lules are very much pointed; whilst in *Didymograpsus bifidus* the
base is round or nearly so, and the denticles are simply submucronate.
Further there are no proofs that the stipes in the latter species ever
attained the great length and breadth displayed by some specimens
of the former.   The frond in *D. bifidus*, Hall, is two-stiped, the
" stipes diverging from the small and short radicle, and curving
slightly inwards, and thence extending in right lines including an
angle of 15° to 20°."   The stipes are narrow, expanding above and
again contracting towards their extremities, the maximum width in
our specimens being about $\frac{1}{12}$ of an inch.   The base is usually obtuse
and gently rounded, but sometimes assumes a more or less pointed
character.   The cellules are on the inner or upper side of the frond,
long, narrow, and slightly curved, about 34 to 36 in the space of
an inch, their apices produced and submucronate.

Loc. Ellergill, near Milburn (upper beds); Eggbeck, near Pooley
(upper beds); and Outerside (lower beds).

16. DIDYMOGRAPSUS SERRATULUS, Hall, sp.
      Graptolithus serratulus, Hall (Pal. New York, vol. i. p. 274,
      pl. 74. fig. 5).

I possess several specimens from the Skiddaw Slates of a species
of *Didymograpsus*, some of which are certainly referable to the

above species, described by Hall from the Utica Slate and Hudson-river Group (Caradoc). Other specimens possess broader stipes and a more open angle of divergence than the true *D. serratulus*, Hall ; but I have referred them with some hesitation to the same species, since I am averse to multiplying species upon imperfect materials, and the preservation of most Skiddaw-Slate Graptolites is such that little more than the general form of the frond can be satisfactorily made out. The only Quebec Graptolite with which this could be confounded is the *D. (Graptolithus) extensus* of Hall (Grapt. Quebec Group, p. 80, pl. 2. fig. 12), from which it is readily separated by the greater width of the stipes and the small size of the radicle in the latter. Further, the stipes diverge horizontally at an angle of 180° in *D. extensus*, but have an upward inclination in *D. serratulus*, and never include a larger angle than 150°. Lastly, the cellules in the former appear to be more closely set than in the latter. Still it must be confessed that some of our specimens approach very nearly to the characters of *D. extensus*, Hall, from which, in the bad preservation of the cellules, they can only be separated by the fact that the stipes invariably incline upwards, at any rate at their commencement.

In *D. serratulus*, Hall, including all our specimens for the present under this name, the frond consists of two long and narrow stipes proceeding from a long and slender radicle, and including an angle of from 115° to 135°, or sometimes even 150°. Variable as the angle of divergence thus seems to be, it may fairly be doubted whether any stress can be laid on this character as a specific distinction. The stipes are narrow at their origin, not exceeding $\frac{1}{40}$ to $\frac{1}{30}$ of an inch, but gradually widening out until a breadth of $\frac{1}{20}$ of an inch may be reached. They usually proceed in straight lines from the radicle, but sometimes they present a slight backward curvature. The axis is well marked, the cellules about 25 in the space of an inch, inclined to the axis at a small angle, with the cell-apertures at right angles with the axis and extending about halfway across the breadth of the stipe. The denticles are angular and not unlike *Graptolites sagittarius*, Linn., for which fragments might very readily be mistaken. In a specimen in my possession one of the stipes shows a length of more than four inches ; so that the entire frond must have attained a very considerable size.

Loc. Outerside and Barff, near Keswick.

Genus DIPLOGRAPSUS, M'COY.

The genus *Diplograpsus* was established by Prof. M'Coy to include those Graptolites which consist of two simple monoprionidian stipes united by their solid axes into a simple linear frond, which is celluliferous on the two sides. The frond is probably always furnished with a radicle at the base ; and in most cases the solid axis is prolonged beyond its distal extremity.

Whilst the generic characters of *Diplograpsus* are thus remarkably clear and unmistakeable, the specific distinctions are unusually obscure. In determining the species of *Diplograpsus* two points are mainly to

be attended to—namely, the character of the cellules, and the nature of the base. The last of these is in most cases by far the most important, since two distinct species may exactly resemble each other as regards the shape of the cellules, and may yet be easily separated by examining the processes at the base, as is the case with *D. teretiusculus*, His., and *D. bicornis*, Hall. This character, however, has been far too much neglected; and though seldom of itself sufficient for specific determination, it affords, when taken in conjunction with the cellules and general shape of the frond, the most valuable aid to a correct diagnosis. So much is this the case that the description of hardly any species of *Diplograpsus* can be considered absolutely free from doubt, unless the nature of the base be distinctly specified. On this view of the importance of the base as a specific character, the species of *Diplograpsus* may be conveniently grouped into three main sections. In the first of these the base is characterized by a median radicle, sometimes very rudimentary, flanked by two lateral processes, of varying length, which spring from the primary cellules on each side, as is seen in *D. bicornis*, Hall, *D. pristis*, His., *D. antennarius*, Hall, *D. Whitfieldii*, Hall, &c. In the second group the two primary cellules are greatly elongated, and form with the solid axis a broad tapering radicle, as in *D. cometa*, Gein., *D. palmeus*, Barr., and *D. acuminatus*, Nich. In these, however, no true "radicle" exists, since the solid axis is not prolonged below the first cellules. In the third group the base is formed by a basal extension of the solid axis, sometimes to a very great length, beyond the proximal extremity of the frond, as in *D. teretiusculus*, His., and *D. pristiniformis*, Hall. It is hardly necessary to remark that this must be carefully distinguished from the extension of the axis beyond the *distal* extremity of the frond, a character common to almost all (probably to all) the known species of *Diplograpsus*.

It is not pretended that these groups are strictly natural; but they embody the three main types displayed by the base of the *Diplograpsi*, and they afford a convenient means of separating the numerous and ill-defined species of the genus. It is quite possible, too, that all the known *Diplograpsi* cannot be referred to any of these three sections; and we know so little of the real significance of the basal processes, that there is some reason to believe that even a single species may at one period of its growth belong to one group, and at a later period to another. Thus I may mention that I have found in the Upper Llandeilo rocks of Dumfriesshire specimens of a *Diplograpsus* undistinguishable in other respects from the ordinary form of *D. teretiusculus* of Hisinger, but provided with two long lateral processes in addition to the basal extension of the axis. This may possibly be a new species, but may with equal probability be merely a particular stage of the development of *D. teretiusculus*, His.

The first and third of these groups are alone represented in the Skiddaw Slates, from which four species of the genus are now known to me—namely, *D. antennarius*, Hall, *D. mucronatus*, Hall, *D. teretiusculus*, His., and *D. pristiniformis*, Hall, of which the first and last are confined to the Quebec Group.

17. DIPLOGRAPSUS ANTENNARIUS, Hall, sp.

Climacograpsus antennarius, Hall, Grapt. Quebec Group, p. 112,
pl. 13. figs. 11–13.

I have obtained several specimens of this remarkable species from
the slates at Outerside, but their preservation is seldom good, as
far as regards any part but the base. The frond is simple and
quadrangular, celluliferous on the two sides, and having the axis
extended beyond its distal extremity, sometimes for more than $\frac{1}{2}$
an inch. The length of the frond varies from $\frac{1}{5}$ of an inch, the
smallest observed, to $\frac{3}{5}$ of an inch, exclusive of the axis; and the
average breadth is one line. The most peculiar and characteristic
part of this Graptolite is the base, which is adorned with three pro-
cesses. Of these, the middle one is a small triangular extension of
the axis, the true "radicle;" and the two lateral ones are long,
setiform, straight or curved processes, springing from the lateral
angles of the base, and sometimes attaining a length of $\frac{1}{3}$ of an
inch, the two including an angle of about 120°. All my specimens
are simply imperfect scalariform impressions; but, according to Hall,
the cellules, which are excavated in the substance of the stipe, are
from 24 to 28 in an inch, "short, nearly twice as wide as long; the
cell-denticles nearly rectangular to the axis."

Loc. Outerside, near Keswick.

18. DIPLOGRAPSUS MUCRONATUS, Hall.

Graptolithus mucronatus, Hall, Pal. New York, vol. i. p. 268, pl. 73.
figs. 1 *a–d.*

Three specimens of this species have come under my notice from
the Skiddaw Slates, though I believe it has not been before observed
to occur below the horizon of the Upper Llandeilo rocks either in
Britain or in America. The frond is bicelluliferous; the cellules
25 to 30 in the space of an inch; the denticles slender, prominent,
and extended into flexible mucronate tips. The axis is usually pro-
longed beyond the distal extremity of the frond; but the nature of
the base is not known.

Loc. Outerside, near Keswick.

19. DIPLOGRAPSUS TERETIUSCULUS *, His.   Pl. V. figs. 11–13.

This species is essentially an Upper-Llandeilo form, though it has
recently been discovered by Prof. Harkness in the Lower Llandovery
rocks, near Haverfordwest, in Wales (Geol. Mag. vol. iv. no. 6). It
was first noticed as occurring in the Skiddaw Slates by Prof. Hark-
ness and myself (see Quart. Journ. Geol. Soc. vol. xxii. p. 480); so
that it is now known to range from the Lower Llandeilo to the
Lower Llandovery rocks, though it is apparently confined to the

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* *D. teretiusculus*, His., and *D. antennarius*, Hall, with some other species,
belong to a section of the *Diplograpsi* in which the cellules are simply excavated
in the substance of the stipe. Hall has placed these in a distinct genus under
the name of *Climacograpsus*; and it would seem advisable in future to accept
this change, though the old names have obtained such a general currency.

upper part of the Skiddaw Slates, and does not occur in their lower portion. *D. teretiusculus*, His., belongs to that group of *Diplograpsi* in which the axis is prolonged below the proximal extremity of the frond in the form of a long and slender radicle. The cellules are simply excavated in the sides of the polypidom; and all specimens appear either as scalariform impressions, or in the form described by M'Coy under the name of *D. rectangularis*. This species is, however, too well known to require any description.

Loc. Common and well preserved in the soft black shale of Ellergill Beck, near Milburn, in Westmoreland.

20. DIPLOGRAPSUS PRISTINIFORMIS, Hall, sp. Pl. V. figs. 14 & 15.

> *Graptolithus pristiniformis*, Hall, Grapt. Quebec Group, p. 110, pl. 13. figs. 15–17.

This is a Quebec species, which is of very common occurrence in the Skiddaw Slates, and is probably the same as the one which was doubtfully referred to *D. pristis*, His., by Mr. Salter in his note on the Graptolites of this formation. (Quart. Journ. Geol. Soc. vol. xix.) It is, however, distinguished from *D. pristis*, His., by the smaller width of the frond, by the greater number of cellules in an inch, and by the character of the base.

The frond is simple, diprionidian, and varying in length from $\frac{1}{2}$ to $1\frac{1}{4}$ inch. It tapers gradually towards the base, the width in the fully developed portion being from $\frac{1}{16}$ to $\frac{1}{12}$ of an inch. The base is furnished with a slender radicle, the length of which varies from $\frac{1}{10}$ to nearly $\frac{4}{10}$ of an inch, the cellules sometimes commencing quite abruptly, sometimes tapering off into the radicle. The cellules are very narrow and closely set, being from 28 to 35 in the space of an inch, inclined to the axis at the very low angle of about 20°, and having about one-third of their length free. The denticles alternate distinctly with one another, their extremities being sometimes acute and sometimes rounded, perhaps more commonly the latter. The axis is generally prolonged beyond the distal extremity of the frond. In one very beautiful specimen, apparently of this species, from the upper beds of the Skiddaw Slates, the apices of the cellules are provided with small mucrones or spines, which have an upward direction. (Pl. V. fig. 22.)

This species is somewhat like *D. angustifolius*, Hall, but is distinguished by the fact that the cellules in the latter are not markedly alternate, and are always rounded, whilst the base is provided (as in *D. pristis*, His.) with three processes.

Loc. Outerside, near Keswick (lower beds of the series); Ellergill, near Milburn, Westmoreland (upper beds of the series).

Genus GRAPTOLITES vel GRAPTOLITHUS, Linn.

This genus should properly be confined to those Graptolites which consist of a simple stipe, with a single row of cellules on one side. The base or commencement of the stipe is marked by a small radicle, and is generally curved, the cellules not attaining their full

size until the straight portion of the stipe is reached. The solid axis would seem not to have been prolonged, in the adult, beyond the distal extremity of the stipe, all apparent specimens of this prolongation having probably been produced by breakage; but this is uncertain.

On this definition the genus would include a large series of forms, of which *G. Sedgwickii*, Portl., *G. sagittarius*, Linn., *G. priodon*, Bronn, and *G. lobiferus*, M'Coy, may be taken as typical examples. As already stated, Prof. James Hall denies the existence of any Graptolites coming under the above definition, referring all examples of such to the breakage of compound monoprionidian forms, such as constitute one section of the unmanageable genus *Graptolithus*, Hall. This objection may possibly, and, indeed, probably, hold good as far as the Quebec group is concerned; but it breaks down entirely when applied to the Graptolitic rocks of Scotland, Wales, Ireland, and the Continent generally; and it becomes impossible for us to question the real existence of a group of perfect adult Graptolites with the characters given above. These, then, and these only, should be included under the genus *Graptolites* or *Graptolithus*. As regards the Skiddaw Slates, which contain numerous branching Graptolites, I certainly am inclined to think that the genus *Graptolites* is not represented, and that the forms originally ascribed to it are in reality fragments only of the compound species. At any rate, no instance has come under my notice of any specimen in which a slender curved base is shown, and all the described simple Graptolites said to occur in the Slates can be readily referred to known compound forms.

Four simple Graptolites have been described from the Skiddaw Slates, viz. *G. latus* by Prof. M'Coy, *G. sagittarius*, *G. tenuis*, and *G. Nilssoni* by Mr. Salter.

21. GRAPTOLITES LATUS, M'Coy. (Quart. Journ. Geol. Soc. vol. iv. p. 223, and Brit. Pal. Foss. p. 4.)

This name is applied to fragments of stipes, common in the Skiddaw Slates, and characterized by their great width and by the triangular submucronate denticles. The species appears really to have been founded on portions of the stipes of *Dichograpsus octobrachiatus*, Hall, *Didymograpsus patulus*, Hall, *Tetragrapsus bryonoides*, Hall, and probably other species. While not representing a true species, the name may be usefully retained as a convenient designation for the numerous specimens which are too fragmentary to admit of specific or generic determination.

Loc. Everywhere in the Skiddaw Slate district.

22. GRAPTOLITES SAGITTARIUS, Linn.

Fragments occur not infrequently in the Skiddaw Slates, which certainly cannot be distinguished from portions of this species; but it is highly probable that they really belong to *Dichograpsus Logani*, Hall, and *Didymograpsus serratulus*, Hall, with perhaps other forms.

Loc. Outerside; Barff; Scawgill, &c.

23. GRAPTOLITES TENUIS, Portl.

Small stipes occur very commonly in the Skiddaw Slates, especially in the upper beds, which appear to be referable to this species.   On a closer examination, however, many of these will be found to branch, and they are probably all fragments either of a *Dendrograpsus*, Hall (which is most probable), or of a *Pleurograpsus*, Nich.; but the specimens are too imperfect to allow of any certain identification.

Loc. Keswick; Barff; Ellergill, near Milburn.

24. GRAPTOLITES NILSSONI, Barrande.

This species is stated by Mr. Salter to occur in the Skiddaw Slates at Braithwaite Brow; but I have never seen any specimen of it.   If this determination does not rest upon a specimen of *G. tenuis*, then *G. Nilssoni* is the only simple Graptolite (in the Slates) which would not, as far as is yet known, be easily referred to a compound form *.

Genus DENDROGRAPSUS, Hall.

I have felt great hesitation in admitting this genus into the list of those represented in the Skiddaw Slates, and have only done so at last on the strength of numerous minute branching fragments, which I have found to occur chiefly in the upper beds of the series. These are always extremely fragmentary and imperfect; but their mode of branching is most consistent with the belief that they belong to a *Dendrograpsus*, though more perfect specimens may demonstrate this to be a fallacy.

The genus *Dendrograpsus* is defined by Hall as including those Graptolites in which the frond is composed of a strong foot-stalk, which is " subdivided into numerous branches and branchlets, which are but slightly divergent, the whole producing a broad, spreading, shrub-like frond."   The genus, with the closely allied *Callograpsus*, Hall, is essentially characteristic of the Lower Llandeilo group, both in America and in Britain.

25. DENDROGRAPSUS HALLIANUS, Prout (American Journal of Science, vol. ix.).   Pl. V. figs. 6 & 7.
   Dendrograpsus furcatula, Salt.   (Mem. Geol. Survey, vol. iii. p. 331, pl. 11 A. fig. 5.)

The specimens in my possession, if really referable to *Dendrograpsus*, accord most nearly with the characters of the above species. They consist of small, very narrow, branching stipes, dividing in an irregularly bifurcating manner, and always occurring in a fragmentary condition.   The cellules are narrow, inclined to the axis at a very small angle, about 24 in the space of an inch; the denticles conspicuous and angular, the cell-mouths being at right angles

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* Whilst this paper has been passing through the press, I have come across several specimens, from the Skiddaw Slates, of an undescribed *Didymograpsus*, in which the cellules have the characters of *G. Nilssoni*, Barr.   Mr. Salter, therefore, probably founded his determination upon a fragment of this species.

to the axis; the whole presenting a strong resemblance to some forms of *Graptolites tenuis*, Portl.

Dendrograpsus furcatula, Salt., founded on some small fragments from the Lower Llandeilo rocks of Wales, appears at present to be undistinguishable from this species.

Loc. Barff, near Keswick; Ellergill Beck, near Milburn in West-moreland.

III. Appendix.

Since the foregoing has been written, Prof. Harkness has kindly placed at my disposal some specimens which he has recently dis-covered near Crummock, and which appear to contain two new species. I have likewise obtained from Mr. Joseph Graham, of Keswick, a species of *Tetragrapsus*, which seems to be new to Britain. Subjoined is a short description of these, as complete as the materials at present obtained will allow ; and I have added a list of all the Graptolites as yet recognized as occurring in the Skiddaw Slates.

26. Dichograpsus reticulatus, Nicholson.   Pl. V. figs. 3–5.

Spec. char. Frond compound, consisting of a short funicle giving off four main celluliferous stipes, each of which gives origin to two secondary stipes at angles of from 60° to 90°. There are no secondary stipes to each main branch further than these two ; nor is there any reason to believe that these in turn give off tertiary branches, though it is possible that such really exist. The first secondary branch is given off at a distance of about $\frac{1}{5}$ of an inch from the funicle, the second at from $\frac{1}{5}$ to $\frac{2}{5}$ of an inch from the first.   Both the primary and secondary branches run in straight lines, being monoprionidian, narrow at their commencement, but ultimately ex-panding to a width of from $\frac{1}{20}$ to $\frac{1}{16}$ of an inch.   The cellules are ex-tremely badly preserved, and it is impossible to say how near to the funicle they may commence.   In some fragments, apparently refer-able to this species, they are narrow, inclined to the axis at an angle of about 20°, with the cell-mouths at right angles to the axis, thus resembling some forms of *Graptolites sagittarius*, Linn.   The denticles are angular, about 25 in the space of an inch, their apices not produced or mucronate.   This very remarkable species exhibits a mode of branching quite unique amongst the *Dichograpsi* ; but it certainly belongs to the group comprising *D. flexilis*, Hall, *D. rigidus*, Hall, and *D. multiplex*, Nicholson, and, like them, it has probably never possessed a central disk.   It is more closely allied to *D. multiplex*, Nich., than perhaps to any other ; but it is easily distinguished by the repeated dichotomous division displayed by the latter species.

Loc. Scale Hill, near Crummock.

Genus Pleurograpsus, Nicholson (Geol. Mag. vol. iv. p. 256).

This genus was originally founded by myself to include those branching and compound Graptolites in which there is no proper

" funicle,"—the essential part of the definition being, that the celluliferous branches are derived from a main celluliferous rhachis, and not from a non-celluliferous funicle.

27. PLEUROGRAPSUS VAGANS, Nich.   Pl. VI. figs. 4 & 5.

Amongst Prof. Harkness's specimens is one which is certainly new, and which appears to belong to this genus.   This determination rests entirely upon the mode of branching, and must therefore be regarded as being simply provisional, since the discovery of a complete specimen might very possibly demonstrate the existence of a true " funicle."

The frond, as far as seen, consists of a main stipe giving off celluliferous branches from one side, at intervals of about $\frac{4}{5}$ of an inch, and at angles of about 60°.   The stipes are narrow at their origin, but widen out until a breadth of $\frac{1}{8}$ of an inch may be obtained. The axis is strong, and the common canal broad and well marked. The cellules are from 20 to 22 in the space of an inch, of the type of *G. latus*, M'Coy ; the denticles angular and prominent, their apices being produced and submucronate.

Loc. Scale Hill, near Crummock.

28. TETRAGRAPSUS CRUCIFER, Hall, sp.

Graptolithus crucifer, Hall.   (Grapt. Quebec Group, p. 92, pl. 5. fig. 10.)

An obscure and weathered specimen, obtained by Mr. Joseph Graham of Keswick, is apparently referable to this species ; but its state of preservation is such as to preclude any certain determination.   The frond consists of four simple stipes united centrally by a small disk.   The stipes are broad, attaining a width of about $\frac{1}{8}$ of an inch, the denticles being angular and submucronate.   *T. crucifer,* Hall, differs from *T. Headi,* Hall, in being smaller, but in possessing broader stipes as compared with the size of the frond.

Loc. Barff, near Keswick.

List of the Graptolites of the Skiddaw series.

Dendrograpsus Hallianus, Prout (?).
Dichograpsus Logani, Hall.
—— *multiplex,* Nich.
—— *octobrachiatus,* Hall (= *D. Sedgwickii,* Salt.).
—— *reticulatus,* Nich.
Didymograpsus bifidus, Hall.
—— *caduceus,* Salter.
—— *geminus,* His.
—— *nitidus,* Hall.
—— *patulus,* Hall (= *D. hirundo,* Salt.).
—— *serratulus,* Hall.
—— *sextans,* Hall.
—— *V-fractus,* Salt.
Diplograpsus antennarius, Hall.
—— *mucronatus,* Hall.
—— *pristiniformis,* Hall.
—— *teretiusculus,* His.
Graptolites latus, M'Coy.
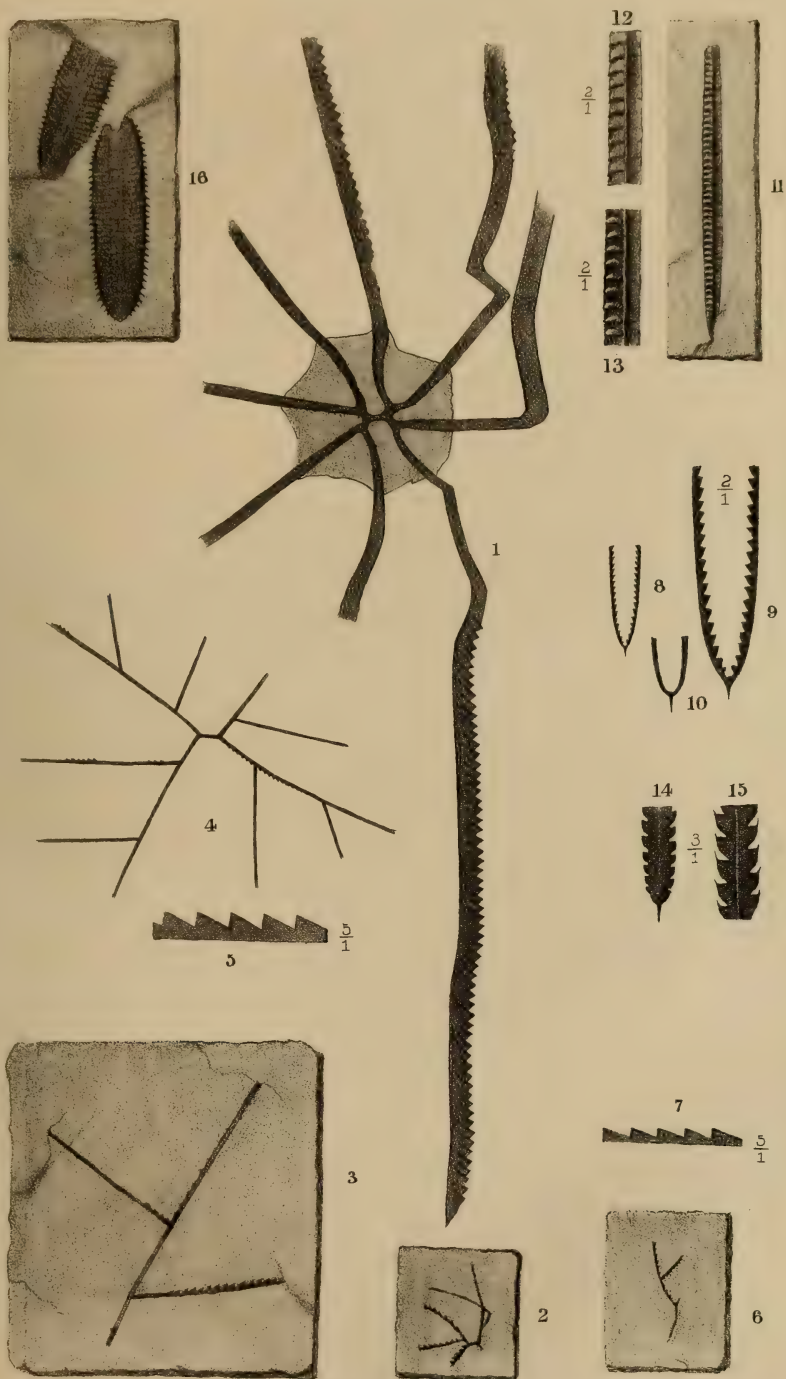
SKIDDAW GRAPTOLITES.

SKIDDAW GRAPTOLITES.

{ *Graptolites sagittarius*, Linn. (?) }
{ —— *tenuis*, Port. (?) }
{ —— *Nilssoni*, Barr. (?) }
Phyllograpsus angustifolius, Hall.
—— *typus*, Hall.
Tetragrapsus bryonoides, Hall (= *Didymograpsus caduceus*, Salt.).
—— *crucifer*, Hall.
—— *Headi*, Hall.
—— *quadribrachiatus*, Hall (= *T. crucialis*, Salt.).
Pleurograpsus (?) *vagans*, Nich.

EXPLANATION OF PLATES V. & VI.

(Illustrative of the Graptolites of the Skiddaw series.)

The figures are drawn from nature, unless it is otherwise stated.

PLATE V.

Figs. 1 & 2. *Dichograpsus octobrachiatus*, Hall:—(1) A specimen showing the central disk, and one of the celluliferous stipes in full: *after Hall*; natural size. (2) A small and imperfect specimen of this species (?) from Mirehouse, near Skiddaw: natural size.

3–5. *Dichograpsus reticulatus*, Nich.:—(3) A fragment from Barff, natural size. (4) A specimen from the collection of Professor Harkness, natural size. (5) Portion of fig. 4 magnified five diameters.

6 & 7. *Dendrograpsus Hallianus* (?) Prout:—(6) A specimen from Ellergill, natural size. (7) A portion of the same, magnified five diameters.

8–10. *Didymograpsus geminus*, His.:—(8) A specimen having the branches not very divergent, natural size. (9) The same, magnified two diameters. (10) Another specimen with a rounder base, natural size.

11–13. *Diplograpsus teretiusculus*, His.:—(11) A specimen from Ellergill, natural size. (12) A portion of the same, magnified two diameters. (13) A portion of another specimen, magnified two diameters.

14 & 15. *Diplograpsus pristiniformis*, Hall:—(14) Base of a stipe, magnified three diameters. (15) A portion of a specimen apparently belonging to this species, in which the cellules are furnished with small spines at their apices: magnified three diameters.

Fig. 16. *Phyllograpsus typus*, Hall. From Barff, natural size.

PLATE VI.

Figs. 1–3. *Dichograpsus multiplex*, Nich.:—(1) A specimen, from the collection of Professor Harkness, showing the funicle (*a*) and the dichotomizing stipes: natural size. (2) Fragment of the same, enlarged to show the form and relations of the cellules. (3) A single dichotomizing stipe, from the collection of Professor Harkness: natural size. These figures have been copied from sketches by the author.

4 & 5. *Pleurograpsus?* *vagans*, Nich.:—(4) A specimen from Crummock, natural size. (5) A portion of the same, magnified two diameters.

3. *On the* GLACIAL *and* POSTGLACIAL STRUCTURE *of* LINCOLNSHIRE *and* SOUTH-EAST YORKSHIRE. By SEARLES V. WOOD, Jun., Esq., F.G.S., and the Rev. J. L. ROME, F.G.S.

<div align="center">(Read November 20, 1867 *.)</div>

<div align="center">I. INTRODUCTION.</div>

THE geology of the Upper Tertiaries in Lincolnshire has not, so far as we are aware, received any general notice ; while in the case of Yorkshire, the accounts given belong for the most part to a date when the views of geologists on the subject were very restricted.

The work of Dr. Young and Mr. Bird upon the geology of the Yorkshire coast was published in 1822, while the more recent and better-known work, the ' Geology of Yorkshire,' by Prof. Phillips, has now been published thirty-eight years. Even the latter of these works long precedes the time when geologists began to recognize the importance of the Drift-series, or the former existence in these latitudes of the arctic and subarctic conditions to which they were due.

These works, and a notice by Mr. Prestwich of the occurrence of *Cyrena fluminalis* at Kelsea Hill, in the 17th vol. of the Journal of the Society, a paper by Mr. Topley " On the physical Geology of East Yorkshire," in the 3rd volume of the ' Geological Magazine,' p. 435, and a notice of the submerged forest at the Hull Docks, by Mr. F. M. Foster, in the ' British Association Report ' for 1866, constitute the only published accounts of the Tertiary geology of this region, so far as we are aware, up to the year 1866. In that year, and while our investigations were in progress, Mr. H. F. Hall, F.G.S., visited Holderness ; and, the results of these investigations up to that time being communicated to him, especially the distinction between the three Boulder-clays of that district and their unconformability, he has, in a paper read before the Liverpool Geological Society, and lately published in their 'Proceedings,' given a description of some of the features of the Holderness coast. The paper, not being illustrated by sections, cannot be easily followed by those not thoroughly familiar with the district ; but, with the exception of the distinction between these three clays, the views of Mr. Hall are at variance for the most part with what appears to us to have been the sequence of geological events in this region.

In his paper on the Lincolnshire Oolites, in the 9th vol. of the Journal, Prof. Morris has given an accurate account of the patch of Glacial clay intersected by the Great Northern Railway at Ponton.

In the able paper by Mr. Judd, " On the Strata which form the Base of the Lincolnshire Wolds," in the last volume of the Journal, a slight reference is made, under the term " peculiar drift," to the Glacial clay which has so magnificent a development in that county.

As the two counties, although containing in common the great natural feature of the " Wolds," which has an intimate connexion with the Glacial and Postglacial structure of the region, yet possess some very distinctive features, it will be convenient in the first place to describe them separately, the north-east of Lincolnshire connecting itself with Yorkshire, and having the same distinctive features from central and south Lincolnshire.

* For the other communications read at this Evening-meeting,

II. The Structure of South-east Yorkshire and North-east Lincolnshire.

As all the beds of this region appear to us to be represented in the Holderness coast-section (fig. 1, p. 148), their description will be much shortened if we give a condensed view of the section afforded by the line of coast from the mouth of the Humber to Speeton, the point where the Northern Wold-scarp and foot is intersected by the present coast.
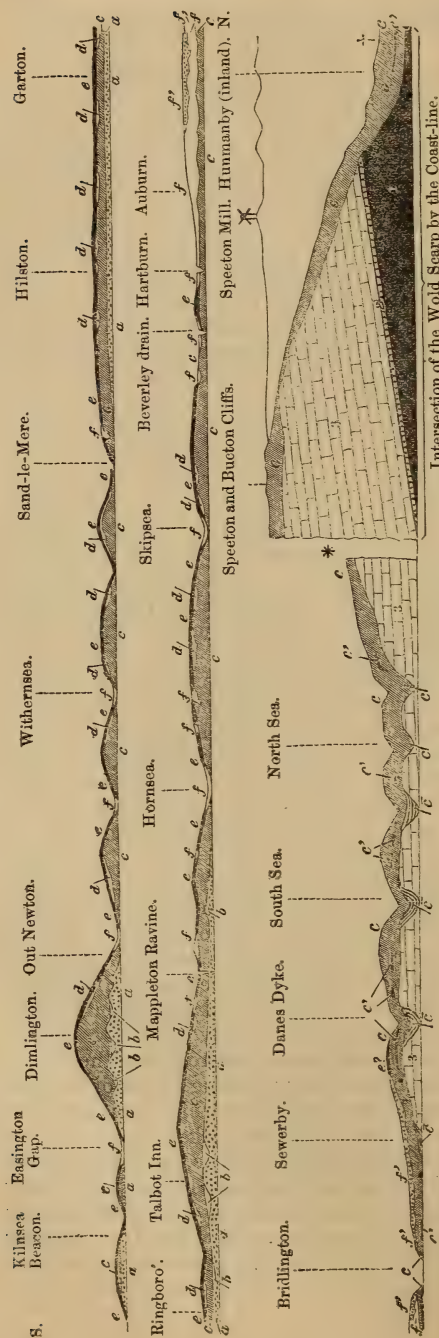
The bed marked *a* of this section, or basement clay of Holderness, forms the oldest of all the deposits above the chalk in these parts. It consists of a lead-coloured clay abounding in chalk débris, accompanied by stones and boulders from all sorts of rocks; and it presents a close resemblance to that wide-spread Boulder-clay of the eastern and east-central counties which is referred to by the first-named of us, in the last volume of the Journal*, as the "Upper Glacial Clay," with which deposit we identify it. This clay (*a*) rises up in only a few parts of the coast, and is overlapped in every direction by another thick bed of Boulder-clay, marked *c* in the section, to which in most of its exposures it presents a very denuded surface, rising up beneath it in bosses, and in some places divided from it by the beds marked *b*. The relation borne to each other by these clays will appear by a comparison of fig. 1 with the eastern extremities of figs. 5 and 11, both of which cut the deposit at right angles to the former. This basement clay, like the Upper Glacial clay of the eastern and east-central counties, appears to be destitute of any but derivative organic remains.

The beds *b*, which occupy some of the depressions formed by denudation in the surface of the basement clay, and sometimes spread irregularly over the bosses, consist of sand with occasional gravels. In some parts their place is taken by bands of clay (partially separated by sands) exhibiting a character intermediate between the clays *a* and *c*. Not unfrequently, however, it is difficult to say where the basement clay (*a*) ends, and the purple clay (*c*) begins; but in other parts the division is very distinct, and the surface of the former is deeply eroded. Nothing whatever exists, to our apprehension, that would suggest any identity between the beds *b* and the thick and continuous Middle Glacial formation of the east of England; but the reverse of this seems from the general structure to follow, the beds *b* being over the clay which we identify with the Upper Glacial clay of the east of England, while the Middle Glacial formation is under the latter. We have not been able to detect any organic remains in the beds *b*, or to learn of any having been procured from them.

The clay formation *c*, which, from its prevailing colour of purplish brown, we term the "purple clay," is that which has the most extensive spread of any bed superior to the chalk in Yorkshire, not only overlapping the basement clay in all directions, but extending far beyond the north scarp of the Wolds in an irregular belt along the coast northwards. It seems to us to be the same clay as that which appears at intervals along the coast as far as the mouth of the Tees, to near

* Quart. Journ. Geol. Soc. vol. xxiii. p. 394 *et seq.*

Fig. 1.—*Coast-section from Kilnsea Beacon to the Buckton Cliffs.*

Vertical scale 500 feet to the inch; horizontal scale of the part between Kilnsea and Bridlington 2½ miles to the inch, of the part between Bridlington and the break in the section 2 miles to the inch, and of the Wold intersection 2 inches to the mile.

1. The Speeton clays.   2. The red chalk.   3. The chalk.   *a.* The chalk or basement clay.   *b.* Sands with gravel.   *c.* The purple clay.   *c'.* Sands and gravels in *c*, inclusive of the "Bridlington crag."   *c̄.* Beds of rolled chalk lumps, being the equivalent of *a*, or of lower part of *c'* further south.   *d.* The Hessle sand and gravel.   *e.* The Hessle Boulder-clay.   *f.* Sands and gravels, of which those at Hornsea are of freshwater origin.   *f'.* Gravel principally composed of chalk fragments.   The *Cyclas*-marls, which the scale of the section does not allow to be shown, occur as follows, viz.:—resting on the Hessle clay (*e*), both north and south of Withernsea, at Garton, at Ringboro', and between the Talbot and Hornsea; resting on the beds (*f*) at Out Newton, Hornsea, and between the Beverley drain and Hartburn; and on the bed (*f'*) north of Bridlington.   The asterisk marks an interval of four miles omitted, in which the Wold gradually rises to the elevation shown in the Wold scarp intersection, maintaining the covering of *c* throughout.   The bed *c* (with *c'* occasionally included) is the only bed covering the Secondary rocks from the termination of this section up to Scarborough.   The base of *c* over the chalk, two miles north of Bridlington, is a blackish-brown clay that seems to recur also (in greater thickness) at Filey Brigg, between the end of the section and Scarborough.   The junction line of 1, 2, and 3 is much obscured by a great slip.   The line from Speeton and Buckton Cliffs by Speeton Mill indicates the continuation of the Wold brow inland, which makes an angle of 45° with the coast line.   † marks the part where the Hertford river rises close to the coast on the inland slope of the mass of *c* intersected by the cliff, and flows away from the sea.

which we have traced it; but we have only examined it systematically as far as Scarborough, to which place the coast-belt of it is continuous. The distinction of this clay from the basement clay becomes very marked where it rests on the chalk Wold, as around Flamborough and Speeton, since none of the intermediate features which characterize its base where it rests on the basement clay exist in this part, no chalk at all appearing in it north of Flamborough. The basement clay occurs only on the eastern and southern side of the Yorkshire Wold, and is there mostly below the beach-line; but the purple clay not only has a place on both sides of the chalk escarpment, but at Speeton envelopes it, occurring on the summit under Speeton at an elevation exceeding 400 feet. The fortunate circumstance, that the very narrow belt of purple clay which has escaped denudation occurs on the coast, thus permits of the condition of the chalk escarpment prior to the purple-clay deposit being seen; for with this exception the whole of the Wold has been completely denuded of it. The fact that this clay envelopes the north scarp and lies also at its foot, while the basement clay is wholly absent from both positions, is one of great importance in reference to the sequence of the events which followed the commencement of the Glacial period. The purple clay alone seems present beneath the Hessle clay in north-east Lincolnshire, while further to the south, by Burgh, the basement clay appears (from a boring mentioned in the Appendix) to occur. The purple clay in its lower part abounds in boulders, being in fact quite dotted with small angular fragments of older Secondary, of Palæozoic, and of metamorphic rocks. These small fragments just take the place of the small chalk débris of the basement clay and its correlative deposit, the Upper Glacial clay of the more southern counties. It is in the same lower portion of the purple clay also that the great blocks most abundantly occur. In the upper portion the small fragments gradually disappear, and the large blocks also become far less frequent, so that the uppermost part (which at Dimlington can be well contrasted with the lower) is scarcely entitled to the distinction of "Boulder-clay." The lower part of the purple clay in Holderness also contains some chalk, but generally in small quantities only; so that we may infer that the portion resting on the Wolds and that which stretches northwards from the Wold-foot at Speeton, which is destitute altogether of chalk, belong only to the upper part of this formation*. Interspersed in the lower and central parts of the purple clay, where the older Secondary, Palæozoic, and metamorphic fragments as well as the large blocks abound, are some beds of sand with gravels. They are of very limited extent and very intermittent. It is from one of these, just about the beach-line, and at a vertical distance, judging from the boring in Bridlington harbour mentioned by Young and Bird, of some 40 feet from the base of the purple clay (including in that term the beds *b* as the base of that clay), that the mollusca first made known by Mr. Bean, and long known as those of the "Bridlington Crag," were, and still occasionally are, procured. The position of the bed

* The reasons for this inference are fully discussed further on, pp. 168–170.

in the midst of the most boulder-bearing horizon of the purple clay most satisfactorily harmonizes with the character of the shells themselves, which, as the late Dr. Woodward observed *, indicate the formation yielding them to have been accumulated " during the climax of the last great age of cold in Britain ;" while position and organic contents appear alike to indicate its deposit to belong to a stage in the subsidence ushering in the purple clay that was prior to the submergence of the higher parts of the Wold.   In a word, it seems to us to belong to the lower part of the purple clay, or that in which there is a little chalk.

Resting upon an extremely denuded surface of the purple clay, and even in some cases upon the basement clay itself, where the denudation, following upon the elevation of the purple clay, has cut through the latter, occur the beds marked d and e.   As both of these are well developed in the generally known section at Hessle, on the Humber, where they rest directly on the chalk, they may be appropriately termed the Hessle sand (or gravel) d, and the Hessle (Boulder-) clay e.   Both of these deposits appear to us to afford the clearest indications of having been formed after the purple clay had been denuded from all that area where the chalk is now exposed, and of having been deposited on the denuded surfaces.   Different both in colour and in character from the purple clay, the Hessle clay can generally be distinguished from it at a glance, being more earthy, less tenacious, and its foxy red colour being variegated by cinereous vertical partings.   Its best characteristic, however, is the presence in it of irregular-shaped fragments of chalk, not abundant, but sufficiently so to make a marked contrast with the chalkless upper portion of the purple clay on which it so frequently rests.   The Hessle gravel d has a considerable but not uniform development under the clay e, being constantly overlapped by the latter †.   Its position, usually in the lower part of the troughs, indicates the shoal conditions which introduced the resubmergence giving rise to the Hessle clay ; and at Hessle quarry the sand-bed (d) is divided from the brecciated surface of the chalk by a thin bed or pan of indurated ripple-marked mud ; and at South Ferriby it is divided from its superincumbent clay by a similar pan ‡.   Generally along

* Geol. Magazine, vol. i. p. 52.

† This overlap may be advantageously studied in the Hessle Railway-cutting, at which place both beds, having overlapped for some miles the denuded purple clay, rest immediately on the chalk.

‡ A short notice of the Hessle beds, by Prof. Phillips, as they occurred forty years ago, having, since this paper was read, been before the Society, it is unnecessary to refer here to the organic remains enumerated by him from the Hessle gravel ; but we would take the opportunity of observing that our remarks as to overlap and shoal conditions assume the contiguity of the shore, which he considers these organic remains to indicate.   That contiguity, however, is equally consistent with the Postglacial age which we assign to this gravel, as with the Præglacial one for which Prof. Phillips still contends, because the period to which we refer it is one when the area embraced in our paper had, after the denudation of the Glacial clay from a large part of it, become land, and one which was followed by the localized subsidence that gave rise to the Hessle clay.   Entertaining, as all must do, the highest respect for the opinion of Prof.

the coast-section we see the Hessle gravel confined to the lower part of the troughs of denudation cut through or into the purple clay, and the Hessle clay (*e*) alone spreading over and enveloping the more considerable hills formed of purple clay, such as that of Dimlington; but occasionally the gravel (*d*) occurs far up the denuded slopes of the subjacent purple clay. The Hessle clay has a general uniform thickness varying from 10 to about 20 feet, and may be said to wrap the whole of Holderness and East Lincolnshire like a cloth, spreading over and enveloping the denuded edges of the basement and purple clays, and beyond them extending some way over the chalk itself, reaching up the eastern slope of the Wolds to elevations approaching 150, and perhaps even 200 feet, but not now maintaining any constant elevation. Beyond that altitude, however, we have failed to detect it. The wrapping nature of this clay, enveloping hill and valley alike up to elevations between 100 and 200 feet, and the posteriority of it to the formation of the valley-system by denudation in the interval that followed the elevation of the Glacial beds, may be seen by figs. 1, 5, and 11, the two latter showing its overlap beyond the purple clay. The valley (or Postglacial) structure thus attaching to the Hessle Boulder-clay is of great importance in showing its total disconnexion with the great Glacial clay-formation with which it has hitherto been confounded; for although the purple clay may, in the sense that it occupies the valley beneath the northern Wold-foot, and also fills ancient valleys north of Flamborough, be called a valley-deposit, yet it was deposited during a submergence that not only involved those valleys but also the lofty Wold-summits, and even much greater altitudes*; whereas the Hessle clay is the deposit of a very partial submergence, not exceeding apparently from 150 to 200 feet, and was accumulated after the valleys had been formed by the earlier Postglacial denudation out of the Upper Glacial clay. Along the coast we lose this clay a little north of Bridlington, where the chalk and purple clay begin to occupy altitudes exceeding 100 feet. Notwithstanding this true Postglacial age of the deposit, the Hessle clay is really a genuine Boulder-clay; and although its boulders are generally of no great size, some of considerable dimensions occur in it. One of these, containing several cubic feet, and covered with glacial striæ, was brought from the Hessle section, and is now in the Museum of the Literary and Philosophical Society at Hull†. The colour of the Hessle clay, coupled with the presence of the chalk-fragments and the boulders in question, seems to show that it has been mainly formed, and its boulders derived, from the

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Phillips, it nevertheless seems to us that if he concedes, as he seems disposed to do, the separate and newer age of the Hessle *clay* from the mass of the clay in section on the Holderness coast, any objection to the age we assign to the gravel becomes removed.

* We infer this great submergence not merely from the absence of chalk, but from the abundance of boulders of Shap granite in the purple clay from Flamborough to the Tees.

† This, we infer, was derived at second hand from the purple, or else from the basement, clay.

degradation of the purple clay, an admixture of material having been introduced from the chalk which had been laid bare of the Glacial clay by the previous early Postglacial denudation. The appearance of this slight chalk admixture is quite dissimilar to that so profusely dispersed in the basement clay and in the equivalent of that clay over the central and eastern counties. In examining the structure of the latter in central Lincolnshire, we have been led to the conclusion that the enormous preponderance of chalk in this portion of the Upper Glacial clay has been caused by the grinding down of the Wolds by a capping glacier; and the contrast between this deposit and the Hessle clay at once suggests that the chalk in the latter has been introduced by no such Glacial action, but by the mere coast-erosion of the Hessle-clay waters, assisted by the transporting agency of ordinary shore-ice. The Hessle clay occupies the gorge of the Wolds through which the Humber passes; but, so far as we have been able to learn (and we have assiduously searched for it), it has no place on the western side of the Wolds, the later part of the repeated westerly denudation having so sharply swept it off on the west of this gorge, that its boundary there is but a continuation of the line of the Wold-scarp from Yorkshire into Lincolnshire. The following section illustrates its position within this gorge, and the manner in which the Humber (with which river the deposit has no connexion whatever) has cut through it.

Fig. 2.—*Section across the River Humber* (5 miles).

1. The chalk.
d. The Hessle sand and gravel.

e. The Hessle clay.
f. Gravel.
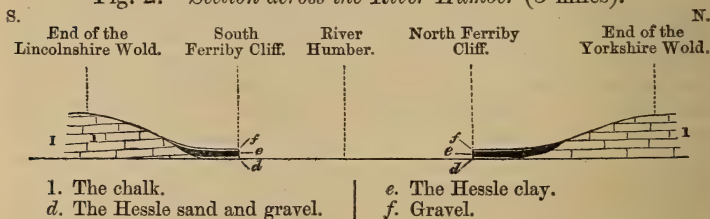
When we consider the height to which this clay rises along the eastern Wold-slope, and over the highest of the purple-clay hills of Holderness, and the manner in which it occupies the Humber gorge, looking, as it were, into the great trough on the west of the Wolds—indeed, slightly entering it—there is no room to doubt its former occupation of that trough; while the manner in which (prior, necessarily, to the existence of the Humber river, whose stream the line of denudation crosses at right angles) it has been cut off by a denudation that has swept north and south along the western Wold-foot indicates that the sea had possession of that trough after the country on the east of the Wolds had entirely emerged from the waters which deposited the Hessle clay.

At the only spot on the Lincolnshire coast which affords a section, namely the low cliff of Cleethorpe, the Hessle clay caps the purple; while the latter is shown by borings there to exist to a thickness of 60 feet, resting immediately on the chalk, without (as is the case also

at Hull) anything like the basement clay intervening.   From Clee-thorpe the Hessle clay extends southwards over the belt of undu-lating ground called "The Middle Marsh," which it envelopes, overlapping the lower part of the eastern Wold-slope.   It is well shown around Alford, where the brick-pits afford good sections, and where it is seen to be overlain by 4 or 5 feet of a light-brown silt, which seems to be of recent origin, and not improbably identical with that near Nocton and Langworth referred to *post* (p. 177).   Four miles south of Alford the Wolds terminate, and the East Lin-colnshire marsh sweeps round to the mouth of the Steeping valley.   Fringing that marsh and forming a belt between it and the high ground, the Hessle clay sweeps round also, and occupies (where it opens on the marsh near Firsby) the mouth of the Steeping valley, which, when describing the structure of central Lincoln-shire, we shall endeavour to show is a valley formed out of the Upper Glacial clay and Cretaceous beds together by that part of the Postglacial denudation which was anterior to the deposition of the Hessle clay.   The southern extension of the Hessle clay beyond the Steeping mouth, near the southern extremity of the Wold, is obscure, owing to the flat nature of the country.

The gravel of Kelsea Hill, the subject of the notice by Mr. Prest-wich [*], is (now that the ballast-pit has been more extensively worked) shown most distinctly to be overlain by this Boulder-clay of Hessle, no less than 15 feet of it being so exposed in one part [†].   Whether this gravel rests upon the basement and purple clays, or either of them, or whether it be the gravel pierced beneath the basement clay in a boring at Sunk Island, elevated for two or three miles round Kelsea Hill, there are no means at present of deter-mining; but we strongly incline to think that the Kelsea-Hill gravel is only an unusually thick and fossiliferous development of the Hessle gravel.   It is certainly singular that, considering the frequent ex-posures of the latter along the coast, none of the organic remains so abundant at Kelsea Hill should occur in them.   These exposures, however, are generally too inaccessible to allow of a proper search for organic remains to be made.   The only gravel-beds on the coast (except that at Paull on the Humber, which rests on the purple clay, and seems identical, as Mr. Prestwich supposes, with the Kelsea de-posit) in which we have been able to detect mollusca belong to the

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[*] Quart. Journ. Geol. Soc. vol. xvii. p. 446.   This Kelsea is near Hedon; there is a Kelsey in North Lincolnshire, five miles west of Castor, near which another gravel occurs, belonging probably to the series described by us in the latter part of this paper under the heading of denudation-beds.

[†] It was a conviction of this inferiority of the Kelsea-Hill gravel to clay then regarded as the ordinary Yorkshire Boulder-clay, and shown in the Hessle section, that led the first-named of us to the opinion (expressed in 1864) that this gravel belonged to the Middle Glacial formation.   The subsequent discovery by us that the clay of Hessle was of distinct age from the great Boulder- (or Upper Glacial) clay formation, with which it had hitherto been confounded, at once negatived that opinion.   It is the 20 feet of red clay full of stones, of the Old Pollard-farm boring, regarded by Mr. Prestwich (vol. xvii. p. 455) as "repre-senting the Boulder-clay," which seems to us to be the Hessle clay which so clearly overlies the Kelsea gravel in the ballast-pit.

series next to be described; and as these are as unequivocally newer than the Hessle clay as the Kelsea-Hill gravel is older than it, there can be no identity between them. As Kelsea Hill is being rapidly removed for ballast, it may be well to show the appearance it now presents by section.

Fig. 3.—*Section exposed in Kelsea-Hill ballast-pit in April* 1867.

West face.   Angle of Pit.   South face.
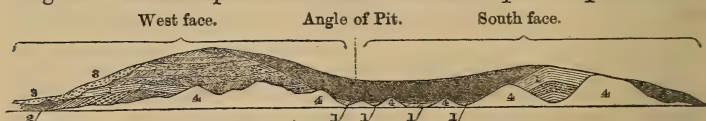
1. Sand and gravel, with shells and some included boulder-gravel.
2. The Hessle clay, with its characteristic small boulders (10 to 12 lbs.) and fragments of chalk.
3. Gravel, probably the equivalent of f of Fig. 1.   4. Talus.

Height of the highest face 35 feet. Some larger boulders (30 to 40 lbs.) were in the pit, but were probably derived from the gravel No. 1.

The remaining sand and gravel beds of the coast-section are divisible into at least two portions—namely, into those marked f, and those marked f', the latter being, near Bridlington, in direct superposition to the former; but whether the whole of those grouped under the symbol f are of precisely the same age, we have no means of determining. Indeed it is not improbable that some of those grouped under the symbol f, such as the gravel at Hornsea, may be even newer than the gravel f' which rests on the beds marked f near Bridlington, and be intermediate between that gravel and the numerous deposits of freshwater marl that form the latest deposits along the coast-section, but which, from the smallness of the scale, are omitted from fig. 1. These f beds all occupy subsidiary valleys excavated through the great valley-deposit of the district, the Hessle clay, and consist either of laminated sands with included gravel-beds, or of gravel only. A considerable bed of this series occupies the valley at Hornsea, and is intersected by the coast-line. On the north of the Marine Hotel at that place, in addition to beds of loam intercalated in, and false-bedded with, the gravel, a loam-bed occurs beneath the gravel (f) 6 feet thick, containing freshwater mollusca in great abundance. At the Hornsea-bridge station (where this bed is in section) the intercalated loam with mollusca is seen to be oblique-bedded, with the gravel at a high angle. The mollusca which we have obtained from this deposit are all purely freshwater forms, existing and common in this country, belonging to the genera *Limnea, Planorbis, Bithynia, Anodonta, Cyclas*, and *Pisidium*; but we were not able to find any traces either of *Cyrena fluminalis* or *Hydrobia marginata*. From no other beds of this series have we been able to obtain any fossils; and their origin, whether freshwater or marine, is therefore uncertain. The most extensive of them is that intersected by the coast between Auburn and Bridlington; and this appears to be the transverse section of a sheet which runs inland towards Driffield, along the base of the inner

(or south-eastern) slope of the North Wolds, and has a thickness of upwards of 25 feet, composed of finely laminated sands with included gravels. Resting on this last-mentioned sheet, deeply indented into it, and overlapping it towards the north, occurs the gravel marked f'. This bed is intersected by the cliff for a distance of four miles, and has a thickness varying from 10 to 20 feet. It is composed principally of hard chalk débris, derived from the adjacent Wold, with some intermixture of flint and fragments of various rocks, derived probably from the purple clay. This bed (which we may assume was deposited horizontally) rises up towards the Wolds on the north of Bridlington until it attains an elevation of nearly 100 feet; but south of that place, towards Auburn, it descends nearly to the beach; from which it would seem to follow, as the coast-section is transverse to the sheet, that some inequality in the elevation of these parts took place at so recent a period as that which followed the gravel f'. All the beds belonging to the f series, although some of them probably are fluviatile, as those at Hornsea, appear to have had their connexion with the sea in the easterly position which it now occupies, and afford the first indication which we meet with of that state of things among the formations that we have been describing.

Capping all the beds from c to f' indiscriminately (but most frequently and extensively resting on the beds of series f) occur numerous deposits of white freshwater marl, abounding with *Cyclas*. That at Hornsea appears to have been the deposit of the mere there, during some earlier, and perhaps historical, period; and a blue clay, associated with the remains of a forest, occurring on the shore at low water, at Sand le Mere, seems to be similarly connected with the former extension of the mere there. Some of these deposits on the higher part of the cliffs may be due to ancient swamps, or may even be the bottoms of dried-up ponds; but it is very remarkable that some of the white marl of this series is, at Paull Cliff, on the Humber, along with the gravel on which it rests, and apparently with the purple clay below it, thrown into a nearly vertical position; and the whole accumulation of marl, gravel, and purple clay together is thrown into confusion *. An extensive sheet of this *Cyclas* marl occurs (resting on the inland extension of the gravel f') at the foot of the eastern Wold-slope to the west of Driffield, along the course

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* A careful drawing of the spot was made by the first-named of us in 1864, as the progress of the works connected with the battery there was likely to conceal the section; but the well sunk there indicates the same thing, the opposite sides of the well-shaft not according with each other. A similar case exists at the brickfield on the north side of Southwold, in Suffolk (by the shore), where, in 1866, a similar white marl with *Cyclas*, resting on several feet of sand and gravel, which rested on the Upper Glacial clay, was, together with the sand and clay, shown to have been thrown into a nearly vertical position. A careful drawing, also, of this section was made by the first-named of us. Can these local disturbances be connected with those greater movements which at a very late period have given rise to the Thames river, as discussed at page 414 of the 23rd volume of this Journal, and to the recent easterly depression of Yorkshire and Lincolnshire to which we allude further on? or are they due to local subsidences produced by some subterranean percolation of water?

of the well-known trout-stream; and this is the only instance in which we have detected inland these beds so frequent in the coast-section. Doubtless this is due to their feeble development rendering them difficult of detection when not in section. These *Cyclas*-marls are not shown in the condensed section No. 1, on account of the smallness of its scale; but the places of their occurrence are given in the reference to the section.

All the beds occurring inland over south-east Yorkshire and north-east Lincolnshire, with the exception of the sands and gravels on the Wold-summit and on the Lincolnshire Oolitic ridge, and also of the marsh or Humber silt-deposits, are, we think, referable to one or other of the beds occurring in the coast-section. These excepted sands and gravels will be more conveniently described in connexion with the denudation-features of the area under consideration, to which denudation we regard them as due. In Lincolnshire, around Ulceby *, are numerous pits of gravel, and some of the Hessle clay, which show the latter resting immediately on the chalk without the intervention of the gravel *d*. It is probable, therefore, that these Ulceby gravels belong to the series *f*; but considering how abruptly the Hessle clay overlaps its gravel, there must always remain great uncertainty in assigning the gravels inland to their true position in the coast-sequence. All the gravels, however, that occur at numerous places along the lower edge of the eastern flank of the Wold, both in Yorkshire and Lincolnshire, belong, we think, either to the beds *f* and *f'* or to the Hessle gravel *d*, and most of them to the former.

On the eastern slope of the Wold, however, at Kirmington, in north-east Lincolnshire (ten miles south of Hull), and at an elevation (as we estimate) of between 100 and 150 feet above the sea, corresponding to the higher limits of the Hessle clay, there occurs a deposit which, unless it belongs to that clay, and forms an estuarine portion of it, as we infer it does, has no place in the coast-section. This deposit consists of a brick-clay interbedded with sands, and capped by a thick bed of large, rounded, or beach-rolled flints. The clay has yielded some horns of a *Cervus*, and also the estuarine or littoral mollusca, *Scrobicularia piperata* and *Mytilus edulis*. Its isolated character (although we believe that it extends into the adjoining parish of Great Limber), coupled with its estuarine fauna, and its occurrence at almost the extreme limit of elevation to which we have been able to trace the Hessle clay, as well as the apparent continuity which it has horizontally with that clay, conspire to indicate that it is a portion of the Hessle-clay formation. The water prevents any attempt to ascertain whether it rests on the chalk or on the Hessle clay. It is far beyond the limits of that part of the purple clay which the denudation had spared.

The only other deposit to be noticed in this description of the south-east Yorkshire and north-east Lincolnshire beds is that disclosed by the borings and excavations at the docks of Hull and Grimsby. The

* This is Ulceby in North Lincolnshire; there is another on the Wold, crossed by the section given in fig. 8.

excavations at Hull we ourselves examined; and they showed the Hessle clay (underlain by the sand *d*, and that again by the purple clay) irregularly denuded and overlain by a bed of silt upwards of 20 feet thick, at the bottom of which were the remains of a forest growing upon, and with the stools in places rooted into, the Hessle clay *. This deep accumulation of silt abounded to the very bottom (where the shells rested on the forest) with the ordinary estuarine mollusca of the Humber—*Scrobicularia piperata, Tellina solidula, Cardium edule, Littorina littorea,* &c. In part this forest-bed was also underlain by the silt, showing an oscillation of level during its growth. We have in this the most unequivocal evidence of a very recent subsidence in an easterly direction, by which the Humber has been introduced over a previous, though still a late, Postglacial land surface. This silt seems to be the same deposit which occupies all the lowest grounds around the Humber and along the north Lincolnshire coast, and is easily distinguishable, by the dark colour and fertility of its soil, from the foxy and less fertile Hessle-clay tracts which it fringes; and this again seems to indicate some oscillation of level since the depression which submerged the forest, because much of this silt (or often blackish clay) deposit is above high-water mark. At Hull the dock-borings showed this forest to be now from 20 to 37 feet below high-water mark of ordinary spring tides, the whole of that depth being occupied by the silt with mollusca and salt water. The borings for the Grimsby Docks disclosed the same forest-bed at still greater depths, varying from 35 to 52 feet below high water of ordinary spring tides, and everywhere covered with silt and salt water. From the Grimsby borings (which were more than 100 in number, and principally carried to depths of from 70 to 80, but in some to upwards of 100 feet below high water) regular sections were constructed by the dock-engineers. An examination of these has satisfied us that the lower part of the purple clay, which, with a thickness varying from 20 to 50 feet (inclusive of the sand- and gravel-beds *c'* and *b*), rests immediately on the chalk, is here cut through by a trough containing sands and gravels of the series *f* before described. These being in places covered by the forest-bed, the depression which has submerged the land surface would appear to have been posterior to the formation of the beds *f*. In some parts there were two forest-surfaces, divided by a bed of leafy clay, from 5 to 15 feet thick, but both newer than the sands which we refer to series *f*. We are informed by the engineer, E. H. Clarke, Esq., that abundance of the stems and roots of the trees were found in excavating the docks. The old troughs thus filled with gravel, and overspread with silt and black mud now converted into land, penetrate the north-east of Lincolnshire for several miles, and give rise to a common feature of this part, called blow-wells. If we are right in referring these submerged troughs of gravel to those marked *f* and *f'* on the coast-section, it follows that not only has there been the recent considerable easterly depression so unequivocally shown by the position of the forest, but this de-

* See section in appendix.

pression has been so unequal that while the gravels of that series under Grimsby descend to 100 feet below high water, they gradually rise in going northwards towards Bridlington, so that their bases, as shown in fig. 1, are considerably above the beach near that place*. We learn also from Mr. Ball, of Brigg, and from Mr. Atkinson, the engineer of the Ancholme navigation, that the remains of a forest which was composed principally of yew and oak exist beneath the marshes of the Ancholme, at a depth of 13 feet below high water of ordinary spring tide in the Humber estuary. This forest is capped by 6 feet of clay, with the remains of freshwater plants, upon which is another and similar forest-bed; from which it would appear that the depression which has so greatly affected the coast twenty miles to the east of the Ancholme has, but in a less degree, also affected the parts inland, so as to bring the site of a forest which had grown in the trough lying on the west of the north Lincolnshire Wold, subsequently to its desertion by the waters of the Hessle-clay sea, once more below the sea-level, and caused it to be overspread with the deposit of the fresh waters of the Ancholme. We have also reason to believe that evidences of this recent easterly depression of a late Postglacial forest-surface, varied by some slight oscillations, obtain further south over the area of the great fen country. The same evidences of a late depression appear to exist along the edges of the Severn Estuary, on the Lancashire, and on some parts of the southern coast, but not, we think, to so great a depth as at Grimsby. Nevertheless, although these evidences of recent depression occur on both sides of England, their general absence suggests that this depression has not been uniform.

In considering the direction in which the purple clay has been denuded, and the action which has brought the scarp of the Yorkshire and north Lincolnshire Wold into the condition we see it now, we have, as we propose further on to show, been led to the conclusion that the Postglacial sea, previously to the formation of the Hessle clay and gravel, had its place on the west of the Wolds, all to the east of them being land, and that the same thing was repeated after the elevation of the Hessle clay. The excavation, therefore, of the troughs containing the series f through the Hessle clay, the relation which they appear to have with the sea in its present place, the formation and subsequent burying of these blowwell channels, coupled with the depression of the land surface at Hull and Grimsby at some period subsequent to the Hessle clay (on which the forest rests at Hull), appear to us to have a manifest connexion with that very recent easterly depression, followed by partial and unequal elevation, which the first-named of us has traced as having affected the country round the Thames mouth †, and which seems to be traceable also in the silting up of the river-valleys of north-east Norfolk, to which the Rev. J. Gunn has called

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* It is impossible to suppose this inequality to be due to the wearing back of the cliff, as these gravels are highest where the cliff yields least, namely north of Bridlington.

† Quart. Journ. Geol. Soc. vol. xxiii. p. 414.

attention *.   Unless we suppose the forest at Grimsby to have grown down to the very level of high water, we must allow an even greater depression than the 52 feet of the Grimsby borings; and it will, we think, occur to all how material an alteration, and in some parts reversal, of the earlier lines of Postglacial drainage such a depression must involve, if, as the position of the *f* beds in fig. 1 seems to show, it were not equal over the area.

Leaving the sands and gravels on the Wold-top and along its scarp-foot, and those of the Oolite ridge of Lincolnshire to be described in reference to the denudation, we pass to the structure of southern and central Lincolnshire.

III. The Structure of Southern and Central Lincolnshire.

The scarp of the chalk Wold extends as a continuous cliff-like † slope from the north-eastern edge of the formation at Speeton, where it is buried in the purple clay, until it reaches the Glacial clay-tract of mid Lincolnshire, which begins near Castor, and is throughout formed of the chalk alone.   South of Castor, however, the western edge of the chalk ceases to maintain this feature, and the cliff-like and regularly continuous scarp changes into ridges of Glacial clay, chalk, and subcretaceous beds together, that rise to elevations equal, and even superior, to that possessed by the cliff-like scarp itself for the southern sixteen miles of its stretch.   From the part where the Glacial clay begins to set in, there is not only no cliff-like scarp, but the edge of the chalk, in common with the Glacial clay, and in some instances with the subcretaceous series also, is denuded into a series of ridges and valleys which run out in various directions, both parallel with, and at right angles to, the subcretaceous outcrop.   This feature has a most important bearing upon the Postglacial structure of the region.

The following sections follow the line of the Great Northern and the Manchester, Sheffield, and Lincolnshire Railways.   The first of them, fig. 4, starts from the north-eastern edge of the large insular mass of Upper Glacial clay which occupies the principal portion of the counties of Huntingdon and Bedford, and part of those of Buckingham and Cambridge (being, except that it is divided by narrow channels of denudation, the second in point of size of the tracts of Glacial beds in England), and is carried north-westwards to the outcrop of the Trias in the valley of the Trent at Newark. The second, No. 5, is carried from the Trias outcrop higher up the Trent valley, north-eastwards to the Holderness coast.   These two

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* Geol. Mag. vol. iv., p. 519.

† In making use of the term "*cliff-like*" we would be understood as distinguishing by it the *continuous* scarp, and not as implying that the chalk escarpment ever formed an actual sea-cliff.   It will be seen that we regard the southern part of it as a Postglacial, and the northern part of it as an Intra- as well as Postglacial *margin of denudation*, partly (at least) marine.   The slope of the escarpment, although, from the disproportion of the vertical scale, unavoidably represented in the sections as precipitous, is, like all the other escarpments, far less steep than the most sloping sea-cliff.

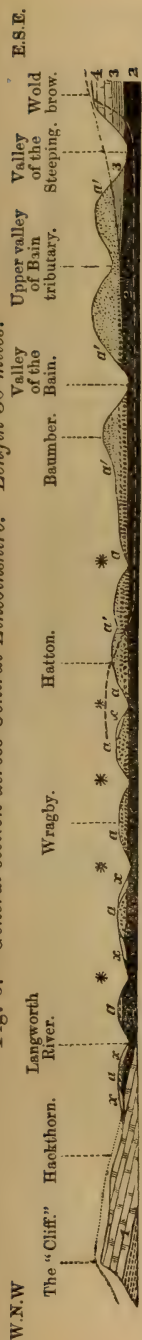Fig. 4.—*Section from beyond the River Nen at Peterborough to the River Trent at Newark.*
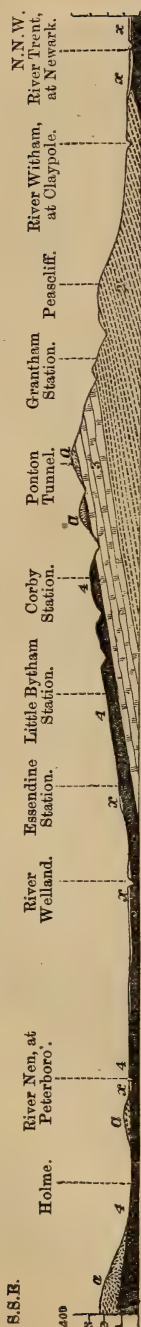
1. The Trias. 2. The Lias. 3. The Lower Oolite. 4. The Middle Oolite. *a.* The ordinary chalky Upper Glacial clay. *x.* Gravels of the valleys of the greater rivers Nen, Welland, and Trent. The vertical scale denotes the height in feet above the sea-level, approximately.

Length of section about 55 miles.

Fig. 5.—*Section from the River Trent to the sea-cliff beyond Aldborough.*
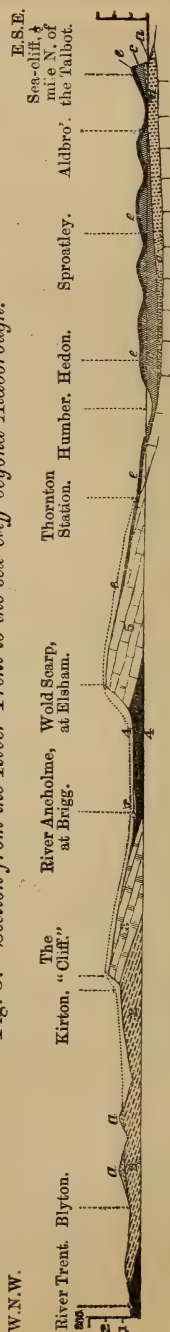
1. The Trias. 2. The Lias. 3. The Lower Oolite. 4. The Middle and Upper Oolites. 5. The Chalk. *a.* The ordinary chalky Upper Glacial clay. *c.* The Purple clay. *e.* The Hessle (Boulder) clay. The beds *b, d,* and *f* of the coast-section (Fig. 1) are omitted. *x.* Gravel formed subsequently to the removal of the Hessle clay. The dotted line indicates the supposed base-line of the Upper Glacial clay before denudation. The "Cliff" both north and south of the point where it is intersected, is capped by the denudation-beds, as shown in Fig. 12, but not about the part where it is cut by this section.

Length of section about 40 miles. The vertical scale denotes the height in feet above the sea, approximately.

Fig. 6.—*General section across Central Lincolnshire. Length 30 miles.*

W.N.W. The "Cliff." Hackthorn. Langworth River. Wragby. Hatton. Baumber. Valley of the Bain. Upper valley of Bain tributary. Valley of the Steeping. Wold brow. E.S.E.

The valleys indicated by an asterisk are those of several parallel tributaries of the Langworth. 1. The Lower Oolite. 2. The Upper and Middle Oolite (Blue clay). 3. The Subcretaceous series (sands with sandstone). 4. The Chalk with the Red Chalk at base. *a.* The ordinary Upper Glacial clay with abundant chalk débris. *a'.* The White clay, formed almost entirely of chalk with great erratics. *x.* Denudation-beds. The *dotted* line indicates the presumed slope of the Glacial sea-bottom. The *broken* line is intended to facilitate a comparison of the section with those numbered 7, 8, and 9 at page 402 of vol. xxiii. of this Journal. At South Willingham (out of the line of section) *a'* is undertain by a bed of gravel, but the bed is of very limited superficial extent.

Fig. 7.—*Section across the valleys of the Bain and the Steeping, from Ellington to the Wold brow at Cawkwell.*

S.W. by S.   Edlington Church. Valley of the Bain. Kiln. Hemingsby House. Highfield Barn. Woldale Trees. Scramblesby. Wold brow at Cawkwell. N.E. by N.
Trough of the Steeping Valley, but occupied by a tributary of the Bain.
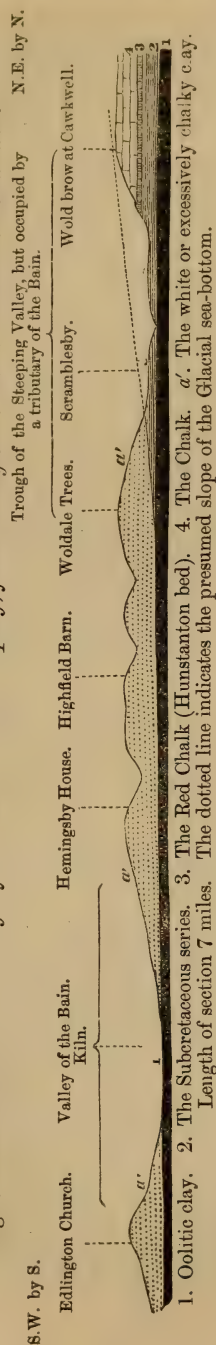
1. Oolitic clay. 2. The Subcretaceous series. 3. The Red Chalk (Hunstanton bed). 4. The Chalk. *a'.* The white or excessively chalky clay. The dotted line indicates the presumed slope of the Glacial sea-bottom. Length of section 7 miles.

Fig. 8.—*Section across the trough of the Steeping valley, from Miningsby to Alford.*
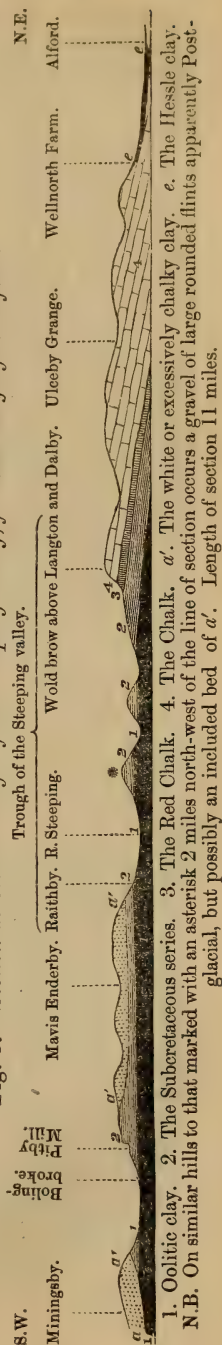
S.W.   Miningsby. Pibby Mill. Bolingbroke. Mavis Enderby. Raithby. R. Steeping. Wold brow above Langton and Dalby. Ulceby Grange. Wellnorth Farm. Alford. N.E.
Trough of the Steeping valley.

1. Oolitic clay. 2. The Subcretaceous series. 3. The Red Chalk. 4. The Chalk. *a'.* The white or excessively chalky clay. *e.* The Hessle clay.
N.B. On similar hills to that marked with an asterisk 2 miles north-west of the line of section occurs a gravel of large rounded flints apparently Postglacial, but possibly an included bed of *a'.* Length of section 11 miles.

sections, each stretching from a great tract of undenuded Glacial clay into the troughs occupied by the Postglacial sea, show the extensive denudation of the Glacial beds which has taken place towards the Trent valley (that is, in a *westerly* direction), both from the northern and from the southern extremities of the area under consideration.

The cliff-like (or continuous) scarp presented by the edge of the chalk everywhere north of Castor is illustrated by the part of the section fig. 5 which crosses it, the only difference being the greater elevations which it attains north of the Humber. Now the section across mid Lincolnshire (fig. 6) shows a structure of which fig. 5, owing to the greater and different denudation of the area traversed by it, affords no trace (namely, that the Glacial clay occupied the extensive depression formed by the eastern slope of the Oolitic ridge, and by the western slope, *not scarp*, of the chalk Wold), and, as it seems to us, will clearly indicate that the cliff-like (or continuous) scarp of the chalk, presented in fig. 5, has been, if not produced, yet augmented and modified by a denudation supplementary to that which has formed the valleys traversed by the section in fig. 6. Fig. 5 (which in this respect may be regarded as illustrating the condition of the entire Wold-scarp from the Purple-clay edge, near Speeton, to the commencement of the Glacial-clay tract of mid Lincolnshire) exhibits no trace of the chalky (or basement) part of the Upper Glacial clay, or of the purple (or upper) part of that clay, or of the more feeble, and Postglacial, Hessle clay, either on the Wold-top or on the western slope; while associated with that feature occurs the cliff-like scarp in question.

Let us now contrast the features of fig. 5 with those afforded by fig. 6, carried across mid Lincolnshire, and intersecting the Wolds where they have no cliff-like scarp.

This section shows that before the Glacial clay was swept away by denudation, the slope formed by the outcrop of the chalk base and of the subcretaceous series was occupied by this clay in great thickness, the occurrence of outliers of it upon the chalk itself proving that it also spread to some distance over the western edge of that formation *.

It is out of the chalk and subjacent deposits, with the Glacial clay bedded up to and over them in solid mass, that the valley-system of mid Lincolnshire has been cut, as from one common bed, by the Postglacial denudation. To all intents, as far as the formation of the valleys goes, the Glacial clay of this part may be regarded as the same bed for the action of denudation as the subcretaceous sands and sandstone whose place it has taken; and as this feature has a special interest in connexion with the structure of the Upper Glacial clay in other parts where similar features prevail, we give the following detailed sections in illustration of it (p. 161):—

Fig. 7 is carried across the valley of the Bain and across that of a tributary of this river; but the latter valley, although its watershed falls into the Bain, owing to a rise in the bottom between

* See fig. 10, *post.*

Scramblesby and Belchford, is really a continuation of the same original trough of denudation as the Steeping valley—as is the case also with the valley intersected by section 11, and with the Bain valley north of the part where section 6 cuts it, this trough running parallel with the Wolds.

Fig. 8 is carried across the south-eastern extremity of the same trough (which is in that part occupied by the Steeping river), and near the southern termination of the Wold. By reason of the Wold narrowing in this direction, we have space to carry this section across it from the Glacial clay of mid-Lincolnshire to the edge of the Hessle clay, where it rises from the low ground of East Lincolnshire. We are thus enabled to see the relative positions of the Hessle clay and of the Glacial clay of mid-Lincolnshire, and the contrast presented by the former as a true Postglacial or valley-formed bed resting against the eastern side of the Wold, to the massive deposit of the latter, out of which and the Wold, together, the trough occupied by the Steeping river has been cut.

In describing the limits of the Hessle clay, we mentioned that at its southern extremity it entered the trough of the Steeping. This circumstance enables us, by carrying a section (fig. 9) from the part where fig. 8 cuts the Glacial clay at Mavis Enderby to the southern extremity of the Wolds, to show the Hessle clay distinctly lying as a valley-deposit in the trough thus cut out of the Glacial clay and chalk Wold. The contrast between the chalky clay a' and the Hessle clay e in this section is too distinct and complete to admit of the possibility of their belonging to the same formation.

Fig. 9.—*Section across the River Steeping, from Mavis Enderby to the Wold-brow at Welton Mill.*

1. Oolitic clay. 2. Subcretaceous series. 3. The Red Chalk. 4. The Chalk. a'. The white or excessively chalky clay. e. The Hessle clay.
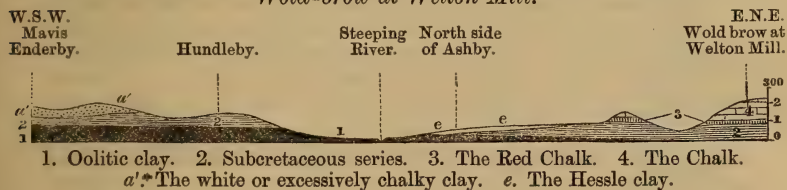
The structure of this trough between the part where (in the condition of a tributary to the Bain) it is crossed by fig. 7, and the part where it is crossed by figs. 8 and 9—a distance of ten miles—is identical throughout in all essential features; and if the section given by Mr. Judd, at page 247 of the 23rd volume of this Journal, be continued beyond Felletby, by the addition west of that place of a solid tract of the Glacial clay, first overlying for a short distance, and then bodily taking the place of the Subcretaceous beds, and resting on the Oolitic clay, down to which the valleys are cut (in the same manner as in the portion of fig. 7 between Scramblesby and Edlington), that gentleman's section will illustrate this trough at the part intermediate between our figs 7 and 8, the bed "b" of Mr. Judd (or "peculiar drift") being the Glacial clay a' of our sections. The same structure obtains also for several miles further

north, until, as shown in fig. 11 (p. 169), the trough enters the
body of the chalk itself near Thorpe le Mere, the Glacial clay re-
maining bedded up to the chalk in that part.

The erosion of the greater part of the Subcretaceous beds, and the
bedding of the Glacial clay solidly against the residue of them, ac-
companied with an overlie of this residue by the clay at a higher
level than the bedded-up portion (which has led to a much greater
Postglacial denudation of the overlying part of the clay), is precisely
analogous to what we find exhibited by the Glacial clay in the case
where it encountered the Subcretaceous sands in Cambridgeshire,
and the Bagshot sands in Essex. In Cambridgeshire, along a
line extending from the chalk at Eversden (where it is overlain by
the Glacial clay, as shown in the section, fig. 7, page 402, of the 23rd
volume of this Journal) towards Bedford, there is the same removal
by the Upper Glacial sea of the greater part of the Subcretaceous
beds, and the bedding-up of the deposit of that sea against the unde-
stroyed part of those beds, as we find presented by our foregoing
sections (figs. 6, 7, and 8) small patches still remaining over the
undestroyed part, attesting the former overlie of this portion by the
Glacial clay *. Throughout central Lincolnshire, where any of the
Glacial clay remains, we see it resting on the shelving edge of what
was the Glacial sea-bottom, formed by the Præglacial slope of the
Subcretaceous outcrop †. We may thus assume that it was the
scour of this sea, in the shallow condition obtaining at the period of
its first entry into the mid-Lincolnshire depression, which destroyed
much of the Subcretaceous series in this part‡.

The hill-ranges of Glacial clay formed by the erosion of the mid-
Lincolnshire valley-system, and traversed by the preceding sections,
are solid masses, equalling in height the chief part of the Lincoln-
shire Wold, being only exceeded by a small portion of it near Sten-
nigate. They even appear to surpass in height the northern part
of that Wold, where, for sixteen miles, it presents the continuous
scarp crossed by fig. 5 ; but the elevations not being given in the
Ordnance maps of this part, we have no means of knowing them pre-
cisely. The western heights of the Bain valley form a continuous solid
range of this clay, that is in effect a continuation of the Wold-brow
for twelve miles from the Heneage Arms Inn to Horncastle. South
of that place the ridge sinks to low elevations, but is continuous to
Kirkby-super-Bain, the whole forming a narrow ridge nearly twenty
miles in length, formed throughout of the Glacial clay. The mass
which divides the Bain valley from that of the Steeping forms an
equally persistent range, ten miles in length, and extending from
near Scrivelsby to Mavis Enderby on the one side, and Wood En-
derby on the other § ; but, having a greater breadth than the former
range, it is denuded into a number of lateral valleys, through which

* In the identical case of the Bagshot sands of Essex, see diagram sections,
figs. 1, 2, and 3, at page 396 of the 23rd volume of this Journal.

† See section, fig. 11, p. 169.

‡ Assisted probably by a preceding Glacier-erosion during the Lower Glacial
period.

§ Fig. 7 crosses the northern, and fig. 8 the southern end of this range.

brooks run to the Bain and Steeping. The true, or continuous, *scarp* of the Wold ceasing about Castor, the *brow* of the Wold is continued thence south-south-east by a lofty ridge of chalk that is denuded on the east or Wold side, as well as on the west, so as to expose the Subcretaceous series on either side of it, that on the east forming inliers. Now the chalk of this ridge (or more precisely, of a spur of it) fits on, as it were, to the Glacial clay of these ranges; and the annexed section (fig. 10) carried along the range and through the junction, will show the way in which this occurs, and how the Glacial clay is essentially to be regarded as having formed one body with the older strata presented to the action of the Postglacial denudation, just as a mosaic of inlaid woods would present one substance of various material to the action of a grooving-plane.

It seems clear from this feature that the form and direction of the ridge which, with the Wold-edge, constitutes the trough of the Steeping valley are not wholly dependent on the direction of the Subcretaceous outcrop, which, in the part traversed by fig. 9, appears to pass directly across it at the Heneage Arms Inn; and that it is the Postglacial denudation alone to which the direction of this ridge is due. But this ridge is an actual continuation of the physical feature presented by the chalk-scarp; and the trough which it forms with the other range, and which is occupied by the upper part of the Bain and by the Steep-

Fig. 10.—*Section passing longitudinally through the ridge prolonging the continuous Wold-scarp.*

1. Oolitic clay. 2. The Subcretaceous series. 3. The Red Chalk. 4. The Chalk. *a'.* The white or excessively chalky clay. *x.* Denudation-gravel. The position of the subcretaceous beds (2) below the Glacial clay is deduced from their position as they come out on the eastern flank of the ridge, which is intersected longitudinally by the section. (Length of section 6 miles.)
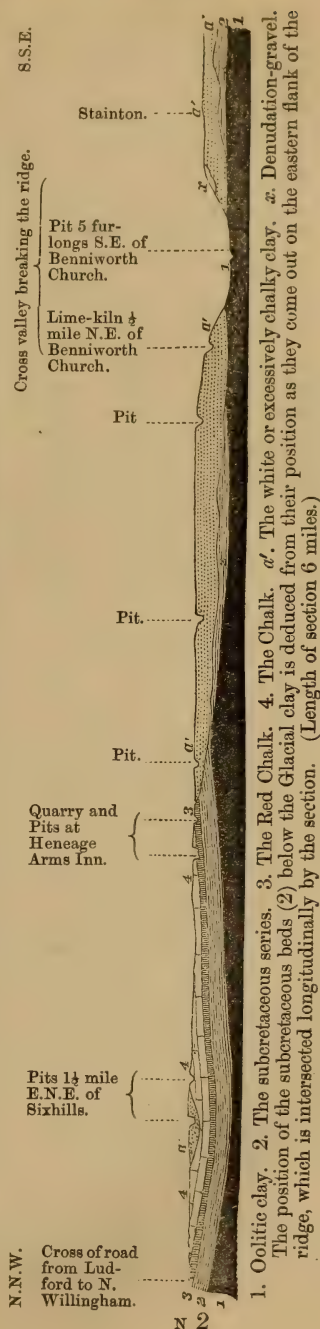
ing, is a symmetrical continuation of the long curvilinear sweep of the Yorkshire and North Lincolnshire Wold-scarp; so that it seems to us to follow, that the curvilinear contour of the western Wold-edge is (in some degree at least) due to the causes which imparted direction to the Postglacial denudation *. Moreover this clearly defined trough is part of one continuous line of Postglacial erosion, which, continuing the Wold-scarp from the northward, is itself continued by the valley of the Wensum and Yare to the south-east (in Norfolk)—a valley throughout formed out of the Glacial beds, and departing far away from the Subcretaceous outcrop. The whole thus forms a great arc or curve of denudation, which, between the Steeping and Wensum, is interrupted by the Fen-country and Wash, but which, from the termination of the scarp at Castor to the end of the curve where the Yare enters the sea, omitting the interrupted part, exhibits the clearest evidence of having been formed by the earlier Postglacial denudation. This interrupted portion appears to us to have been occupied by that one of the arms of the later Postglacial sea which stretched from the eastward up to Hitchin, where it was divided from a similar arm coming up from the west by an isthmus indicated by the close approach in that part of the two principal tracts of Glacial beds in England. These arms are represented by the troughs crossed by the sections, figs. 7 & 8, at page 402 of the 23rd volume of this Journal.

The Glacial clay (a' of our sections, figs. 6, 7, & 8) is almost exclusively composed of degraded chalk—very little of other material, and comparatively few boulders of distant rocks, being present. Unlike the purple clay of Yorkshire, however, where, in addition to the large blocks, the small erratics of Palæozoic and older Secondary rock swarm, the fewer erratics, other than flint, of the clay of mid-Lincolnshire are generally of large size, rivalling the enormous blocks which, derived by coast-waste from the lower part of the purple clay, strew the Holderness coast. This extremely chalky clay appears (from information obtained by us from persons employed in land-drainage and well-sinking) to rest in places on the lead-coloured Glacial clay with chalk of the lower grounds; but in others we found it resting directly on the Oolitic clay. In some parts, as at Bolingbroke, it clearly passed downwards into the less chalky clay which preserves so constant a character over eastern and east-central England, which in mid-Lincolnshire itself is the surface-bed where greater denudation has taken place, and which on the Holderness coast underlies the purple clay. As the Upper Glacial clay in parts of Hertfordshire and Essex, and in one part of Norfolk, is nearly as chalky and white as this clay a' (although more tenacious), there appears to us nothing by which the latter can be distinguished from the general mass of the Upper Glacial clay of these

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* It is by no means unlikely that this great arc of denudation, as well as those referred to at page 400 of the 23rd volume of this Journal, may have had their forms determined by the influence exerted by some prior condition of the Subcretaceous outcrop upon the forces producing the Postglacial denudation, giving rise to the direction which was imparted to it.

and other parts of the east of England; and although in the immediate neighbourhood of its origin, the Lincolnshire Wold, it seems to overlie *, and towards the Wold a little to overlap, the clay which is identical with the wide-spread Glacial clay of eastern and east-central England, yet we conceive that as the débris of which it is composed was carried further out, it became intermingled with, and undistinguishable from, the general deposit of that part of the Upper Glacial sea, its excessive chalkiness diminishing as the distance from the Wold increased. At one place, South Willingham, this excessively chalky clay a' is underlain by a gravel-bed, but one of very limited extent, scarcely a square mile in area. This gravel does not seem to us to have any connexion with the Middle Glacial gravel of the east of England.

The formation of this clay appears to us to have arisen from the immense volumes of degraded chalk which were produced and protruded into the sea by the action of a continuous or capping glacier enveloping the higher elevations of the Wolds †. The nature and appearance of such a glacier is described to us, in the case of that at Cape York, by Dr. Sutherland, in the 9th volume of the Society's Journal, who says that the surface of the land around Baffin's Bay, both high and low, is now enveloped by a mass of ice which is constantly in motion towards the sea. It seems to us that when the Glacial sea first entered the depression crossed by fig. 6, the supply of chalk was less, and was intermingled with material brought from other parts, by which the ordinary lead-coloured clay with abundant chalk resulted; but as the cold increased, and the glaciers gathered thicker and became continuous, the chalk débris increased until almost the entire sediment of this region consisted of it ‡. As we find this chalky clay passing over part of the chalk of the Wold, it is clear that some elevations higher than the parts where it now occurs existed, whence a supply of the material can have proceeded. These greater elevations, we may infer, were those lofty summits which now rise in the north-western part of the Yorkshire portion of the Wold to elevations of 800 feet. So

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* No doubt is entertained by the first-named of us that this white clay of Lincolnshire is the same as a precisely similar deposit worked (like this) for lime, at Hedon in Norfolk, and brought first to his notice by Mr. Harmer, of Norwich; it is seen in a section in that neighbourhood to rest on an eroded surface of the ordinary Upper Glacial clay of that county. This deposit, so resting on the Upper Glacial clay, is undistinguishable, except by position, from the chalky marl *underlying* the Upper Glacial clay, into which the Cromer coast- (or Lower Glacial) beds pass in their western direction inland.

† The very loftiest eminences of the Hertfordshire chalk, such as those near Ivinghoe, may have, similarly to the Wolds, been sources of supply to the chalky Glacial clay that occupies the lower elevations of those parts, and given rise to the greater chalkiness of the clay over some parts of Herts and borders of Essex, although the *nodules* of chalk in this are from the hard Yorkshire part of that formation.

‡ The anomalous case of this extensive deposit of chalky clay being quite destitute of any but derivative organic remains may, perhaps, have been due to the poisoning of the water with this excessive chalky sediment, since we see that the purple clay is not so destitute of organic remains.

soon, however, as the higher elevations were submerged, the chalk débris would cease; and this is the feature presented by the upper portion of the purple clay of Yorkshire, whose purple material seems to us to have been principally derived from the degradation of those Carboniferous and older Secondary rocks that in the north of Yorkshire, and of those Silurian rocks that to the north-west of that county, rise to far greater elevations than the loftiest parts of the chalk area, and which, under the degrading power of an arctic climate, would remain a source of copious sediment after the Wolds had been completely submerged.

The elevation which the clay with chalk débris attains along the western edge of the Wold, without any trace of the purple clay remaining over it, contrasted with its low position beneath the purple clay on the eastern side, seems to us to require the concession of a very considerable Postglacial elevation of the western Wold-edge at the expense of the eastern. The edge thus elevated into a crest is the feature common to most of the arcs or curvilinear sweeps of elevated country that have so intimate a connexion with the direction of the Postglacial denudation, and of one of which, as before mentioned, the Wolds form the principal part.

The next section, fig. 11, carried from Rand (about the centre of the Præglacial depression of mid-Lincolnshire) over the Wolds, and thence to the Holderness coast, will best show the place of the chalky clay on either side of the Wolds, and the position of the purple clay relatively to it, the section beneath it representing what we suppose to have been the relative positions after the deposition of the purple clay, and before the disturbances giving rise to the Postglacial emergence and denudation had begun. There is, however, one circumstance connected with the position of these two clays that requires consideration, which is, the similar absence of all chalk in the purple clay beneath the northern Wold-foot at Speeton to that which obtains where it rests on the Wold-top there and towards Flamborough. As the Wold in Yorkshire rises in its north-western part to elevations approaching 800 feet, we should expect to find a similar accumulation of chalky clay along that part of the Wold-foot where the presence of the purple clay shows it to have escaped the Postglacial denudation, to what we find both in mid-Lincolnshire and on the east of the Wold in Holderness; but nothing of the sort is there.

This has, it would seem, been assumed to be the result of the direction of the drift having been from north to south; but an examination of the case will, we think, show the inadequacy of such an explanation to account for the feature.

Waiving, for argument's sake, the improbability of the drift of an ice-blocked sea being so absolutely constant in direction as not to permit of any débris from the Wold being carried even the shortest distance northwards, we see that there is a total absence of chalk débris in the clay that rests on the scarp-slope itself. Moreover the general east and west direction of the northern Wold-scarp, for 20 miles west of Speeton, would render a southerly

Fig. 11.—*Section from Rand to Dimlington Cliff.*

S.W. by W.

N.E. by E.

Rand.

The Torringtons.

Sixhills.

Thorpe-le-Mere.

Wold Newton.

Holton-le-Clay.

Cleethorpe Cliff, boring through 85 feet of *e*, *c*, and *b* into the chalk.

Humber estuary.

Dimlington Cliff.
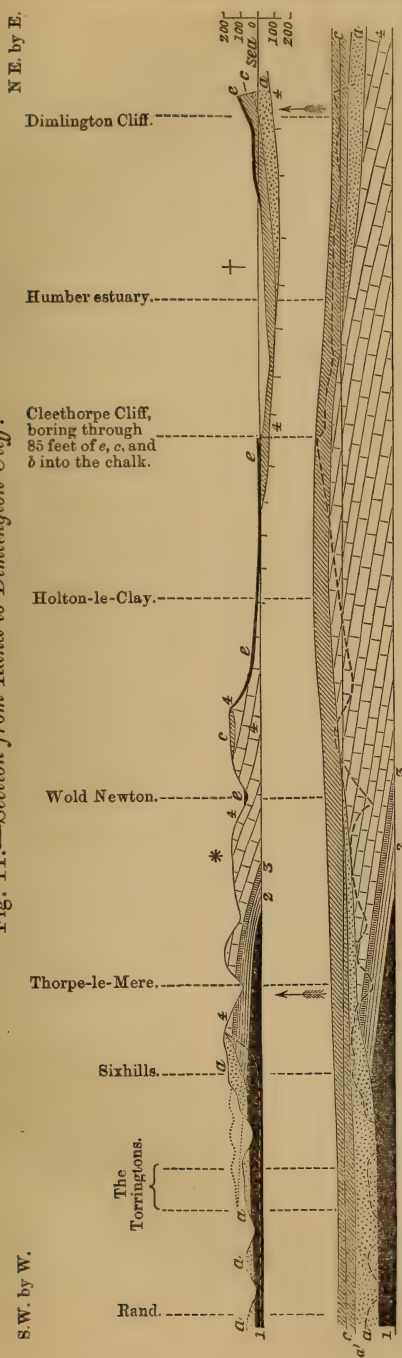
1. The Oolitic clay.   2. The Subcretaceous series.   3. The Red Chalk.   4. The Chalk.   *a.* The chalky portion of the Upper Glacial Clay.   *c.* The purple portion.   *e.* The Hessle clay.   The beds *b*, *d*, and *f* of Fig. 1 omitted.   The asterisk marks the place where, half a mile north-west of the line of section, 6 ft. of the chalky clay (*a*) rests on 20 ft. of gravel, similar to that occurring under *a* at South Willingham.   † indicates the position of Sunk Island, 2 miles north-west of the line of section, where two borings showed the chalk 115 feet from the surface, beneath a little of the chalky clay (*a*), and some of the purple (*c*); but the latter was principally removed and replaced by gravel and silt.   The outlier marked *c*, near Wold Newton, is believed to belong to the purple clay; but if not it can only be a portion of *e*.   It is, however, unlike *e*, and above the general elevation of that formation elsewhere.   The broken line in the bottom section represents the denudation that has resulted on it to form the upper or actual section.   The horizontal line in the lower section represents the supposed sea-level during the deposition of the chalky clay (*a'*).

The broken line in the upper section represents the denudation that has taken place where the Wold has a continuous scarp.

N.B. If the line of section were drawn a few miles further north (say, from West Raisen instead of Rand), the position of the Subcretaceous beds would show that the slope made by the Glacial sea-bottom, across the Subcretaceous outcrop, was less steep than in this section—that outcrop now running out in the manner indicated by the dotted lines in the upper section, except that, from the lower position of the outcrop near Raisen, these lines are unavoidably at too high a level correctly to represent the case.   The arrows indicate the parts where the greatest Postglacial elevation seems to have taken place.

drift in that part impossible until the crest of this scarp had become submerged, until which event the set of the current must have been either east or else west along the shore formed by the scarp itself.   If, as can scarcely be doubted, the chalk, so profuse in the basement clay of Holderness, and tolerably abundant in the lower part of the purple clay of Holderness (a district lying east and south-east of the Wold), was derived from the high part of the Wold country which was then above water, and if free water existed over the equally low part beneath the northern scarp at Speeton, while the scarp ranges westwards from that place up to elevations of 800 feet, how can we suppose this low part to have escaped the chalk débris, if these relative elevations, or anything like them, had then come into existence ?   Further the scarp trends from Speeton in a north-westerly direction, past Hunmanby to Folkton ; and it is precisely in such a direction that the blocks of Shap granite, not unfrequent in this clay, have come.   Again, there is a similar absence of chalk débris in the purple clay that occupies the vale of York at Gate Helmsley, from near which place the Wold-scarp runs north-eastwards for 30 miles at extreme elevations, as well as a similar absence of the basement clay ; but it is in the same direction as that in which Gate Helmsley lies, relatively to the north part of the Wolds, that the chalky Glacial clay stretches to North Warwick-shire ; so that if the chalk that forms the principal ingredient of the Glacial clay of that part were derived from any point south of the north-western angle of the Wolds, it would involve a still less southerly direction of the drift than that which would strike Gate Helmsley.   Further, the chalkless* purple clay of the south side of Flamborough Head, shown in fig. 1 to rest on the beds of chalk-débris $\bar{c}$, is at as low a level as that at Speeton Wold-foot, but 5 miles south of it, *and therefore quite within the set of any such supposed southerly drift.*   Finally, there is the case of the lead-coloured sediment of which the basement clay is composed.   This clay, from its exposure at Kilnsea, in the south of Holderness, to Skipsea, in the north of it, is quite homogeneous, and similar to that which stretches to the Thames heights and to Warwickshire. If, however, the Glacial-clay sediment were deposited under the conditions of such an undeviating southerly drift as supposed, how are we to explain the absence of this leaden-coloured sediment everywhere to the north of Skipsea ?   It is clear that it could not be supplied by the chalk Wold which intervenes between that place and Speeton ; and yet, over all this intervening part, as well as at Speeton, and thence northward, the Glacial clay is composed exclu-sively of the purplish-brown sediment which forms the clay (c) that rests upon the basement clay (a) further south ; while *still further south*, at Grimsby, we get, by overlap, the purple clay (c) again rest-ing directly on the chalk.

* There may not be an absolutely complete absence of chalk here ; but it is sufficiently so to be in total contrast to the basement clay of Holderness, not many miles to the southward, while it is in intimate resemblance to the upper part of the purple clay that caps this basement clay along the coast.

When all the circumstances thus analyzed are weighed in con-
nexion with this southerly-current hypothesis, they seem to us to
form a conspiracy of facts so much in conflict with it as to render
that hypothesis, if not impossible, yet in the highest degree im-
probable.

One explanation of this seeming inconsistency offering itself to us
is suggested partly by the denuded and embossed condition of the
surface of the chalky, or basement, clay of Holderness, upon which
the purple clay rests, and partly by the circumstance of a scarp to
the chalk having been formed in this part prior to the deposition of the
purple clay, so opposite to what we see to have been the case in part of
Lincolnshire previously to the deposition of the chalky clay. We might
infer from this that, after the deposition of the chalky portion of the
Upper Glacial clay, under the conditions of a partial submergence only
in the north of England, an Intraglacial elevation of Yorkshire took
place—an elevation altogether prior to that general one which in-
troduced the Postglacial period — accompanied by the sweeping
off by denudation, during the process, of all the chalky clay from
that area, and followed by the erosion of the chalk edge into the
scarped condition in which we see it enveloped in the purple clay
at Speeton; the portion of the chalky clay remaining under Holderness
having been deeply denuded under shallow-water conditions, which
gave rise to the gravels marked *b* in the coast-section (fig. 1), and to
the intermediate bands of clay that seem in parts to take the place of
the beds *b*.   After this it would then seem that the resubmergence
(which was so great as to cover the loftiest Wold-summits where
denudation-sands exist, and within about 150 feet of which summit
an outlier of the purple clay remains) was either too rapid to permit
of the accumulation of chalk débris from the Wold, or else that it
took place after an amelioration of climate had occurred, sufficient
to melt the glacier producing that débris, but not sufficient to
prevent the formation of floe-ice adequate to the transport of the
large blocks which abound in the purple clay.

Another explanation offering itself to us is suggested by a peculiar
feature presented by the northern scarp of the Wold itself ; for, if the
Ordnance Map be closely examined, it will be seen that the northern
scarp of the Wold coincides, even to sinuosities, with the strike of the
moorland ridge (whose lower continuation runs down through Scarboro'
into the sea at Filey Brigg, and is intersected by the section, fig. 13);
and that the denudation which has formed the northern scarp has taken
its direction from the resistance offered by the unyielding strike of this
Oolitic hard rock of the opposite side. It does not seem improbable,
therefore, when read by the light of Dr. Sutherland's description of
the shores of Greenland, that the sea was, during the period of the
chalky clay, kept out of the northern Wold-foot and vale of York by
a glacier filling this great depression, and that this, confined between
the ridge of the Wold and that of the moorlands, did by its forward
motion towards Malton, and thence round into the great depression
of the vale of York and so south towards Central Lincolnshire,
scarp the Wold, and impart this striking identity to the two sides

of the upper end of the trough containing it. Such a glacier, melting beneath the sea after the submergence had taken place which gave rise to the purple clay and spread it over the higher Wolds, would leave a void in the part where it had existed and kept out the sea during the chalky clay deposit, and this void would then become filled with the purple clay. This alternative, which acquires some countenance from the remarkable rise in the floor of the great depression immediately south-west of Malton, seems to us far the more probable of the two suggested *.

The position of the purple clay on the summit of the lofty Wold at Speeton, as well as the absence of any kind of chalky débris in all but the lower portion of the same clay in Holderness, seems to us to point to the conclusion that the submergence giving rise to it involved Lincolnshire and the more southern parts of England as well as the Yorkshire Wold. As these parts, however, were more remote from the probable source of the purple-clay sediment (which was the Older Secondary and Carboniferous region of Northern Yorkshire, and of the Westmoreland and Cumberland Fells), this portion of the Upper Glacial clay may have attenuated southward; but, however this may be, it has all been removed in that part by the marine Postglacial denudation, the increased operation of which southwardly and westwardly, and its great prolongation over the south and south-west of England, it was the endeavour of the first-named of us to show in the paper before referred to in the last volume of this Journal.

The denudation of the purple clay is, from its present position (stretching northward in a continuous belt along the coast, but wholly removed for a great distance westward, i. e. inland), shown to have proceeded in the opposite direction to that in which the North Sea occurs, the entire Wold-surface of Yorkshire and North Lincolnshire being, with this exception (and that of an outlier, about a furlong square, which still remains at Huggate, near the opposite or western extremity of the Wold, at an elevation of about 600 feet), destitute of it, as well as the low country at the Wold-foot from Muston westwards. An outlier of what seems to be the same clay first meets us westwards from this coast-belt, at a distance of about 25 miles, namely, in the deep railway-cutting at Gate Helmsley, 6 miles E.N.E. of York (whence the same clay occupies much of the ground northwards by Flaxton and Barton Hill), and thus attests

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* In the paper of Mr. Judd upon the Speeton clay, read before the Society subsequently to this of ours, the section of Filey Bay was shown as including a Præglacial forest-bed beneath the Glacial clay. The presence of such a bed would, if it existed, seem fatal to the second of the above explanations, since the grinding of such a glacier as we have supposed would have quite destroyed so feeble a deposit as a forest-bed. The last-named of us, however, in a reexamination of the coast, since Mr. Judd's paper, and during a favourable exposure, after storms, of the cliff-base, not only failed to detect any such bed, but disclosed a lignite (of Kimmeridgian age) containing the impressions of Ammonites, occupying for a considerable distance the part indicated, and overlain directly by the purple clay, the resemblance, as far as the eye is concerned, to the forest-bed of the Norfolk coast beneath the Glacial clay being sufficiently striking.

the original occupation of this part by it. Northward, although we have not examined the coast beyond Whitby, and between that place and Huntcliff, yet, from what we have there observed, we think that the connexion between the Glacial beds of the north of England (and possibly also those of Scotland) and the Glacial beds of the south will be found to exist rather with the purple portion of the Upper Glacial clay than with that older portion of it containing the abundant chalk débris, which to the south of Northeast Lincolnshire is that which the Postglacial denudation has alone spared, but which stretches in tracts of all dimensions from the parts described in this paper to the northern brow of the Thames valley, and from the Suffolk coast to near the borders of Staffordshire. In such case, since the chalk débris occurs in it in profusion as far as 70 miles from the nearest edge of the chalk-formation, we shall scarcely be able to resist the conclusion that the north of England was land after all the south of it had become submerged, since, if the whole went gradually down together, without any such intermediate elevation of the northern part, and the destruction there of the chalky clay, or else some such defence of the northern depressions by glaciers from the entrance of the sea, as we have supposed, why does not this profuse and widely diffused chalk débris occur northwards from the Yorkshire and Lincolnshire Wold?

It would follow also, if our view of the identity of the purple clay with that of the North of England be correct, that all the Glacial beds of the east and east-central of England are represented by the grooved and polished rock-surface upon which, in Durham and Northumberland, the Glacial clay, according to the reports* of of the Tyneside geologists, rests. The beds of chalk débris, marked $\bar{c}$ in fig. 1, seem to belong to the same glaciated land-surface immediately preceding the purple-clay submergence, and to be the latest tailing off inland of that vast chalky redeposit produced by the Glacial degradation of the Wolds which furnished, through all the period of the Upper Glacial clay of the east and east-central of England, the principal ingredient of that clay. It is the same hard stony chalk as that of which these beds marked $\bar{c}$ are composed that is so abundant *and exclusive* in the Glacial clay of the heights on the north side of the Thames valley.

As the true Postglacial Boulder-clay of Hessle extends down to the edge of the marsh surrounding the Wash, and probably partly underlies it; and as the estuarine Postglacial brick-clay of the Nar valley, described by Mr. Rose †, occurs immediately on the east side of the Wash, an identity between the two deposits naturally suggests itself. It would require, however, an intimate knowledge of the country immediately surrounding the Wash to bring these deposits into a satisfactory correlation. An industrious search for the organic remains of the Scrobicularia-brickclay of Kirmington and its neigh-

* See especially a paper, by R. Howse, " On the Glaciation of the Counties of Durham and Northumberland," in the Transactions of the North of England Institute of Mining Engineers for 1864, p. 169 *et seq.*

† Phil. Mag. vol. vii. p. 197 ; Geol. Mag. vol. ii. p. 8.

bourhood, regarded by us as an estuarine portion of the Hessle clay, might much contribute towards the solution of that point.

The presence of *Cyrena fluminalis* in the Hessle gravel, assuming the Kelsea-Hill bed to belong to that formation, suggests an identity between that gravel and those earlier Postglacial formations occurring at Erith, Crayford, Ilford, West Hackney, and Grays in the Thames valley, and at Gedgrave and Sutton in Suffolk, Clacton in Essex, Chislet in Kent, and along the Cam, which have yielded this shell. The negative evidence afforded by its absence in numerous other Postglacial beds partakes of the unsatisfactory character always attaching to that description of evidence; but in looking at the subject in the broader light of the sequence of Postglacial denudation, that identity becomes strengthened; for since these earlier Postglacial deposits are, by the first-named of us, traced in this way as belonging to that portion of the period which was anterior to the denudation of the Weald valley, and was occupied in the Thames region by the denudation which descended from the Glacial clay through the Lower Tertiaries to the chalk, so the Hessle gravel obviously succeeded a period of lengthened Postglacial denudation, during which we see, from the condition of the Wold-brow, that the land had emerged at least 800 feet from the Glacial sea. On the other hand, the formation of this gravel was succeeded by the time necessary to produce a local depression of not less than from 150 to 200 feet (which introduced the Hessle clay), by the formation of the quiescent deposit of that clay possessing an original uniform thickness of nearly 20 feet, by a reelevation coequal in extent, by the formation of the deposits of the *f* series, and, finally, by the changes which have elevated the low land of much of the western Wold-foot above the sea, and depressed part of that on the east, on which grew the Hull and Grimsby forest, as much as from 33 to 52 feet beneath it. Reasoning in this way, and having regard to the probably greater rapidity with which marine denudation during emergence proceeds, over that of deposit during subsidence, we seem to have evidence here of a period following the Hessle gravel, not inferior in duration to that which the first-named of us traces as having followed the formation of the Thames-valley deposits *, and which, he considers, was in that area occupied by the denudation of the Weald valley, by the reversal of much of the drainage, and by the introduction of the Thames river over a forest—a period to which the gravels of several great river-valleys and other late Postglacial deposits appear to us to belong.

In Yorkshire and Lincolnshire we possess the greatest sequence of deposits, from the climax of the Glacial period to the present time, which any part of England has yet afforded. So far as it is a guide, there appears to have been a gradual, but unbroken, amelioration of climate, and no indications of anything affording ground of inference that any recurrence or alternation of severe conditions of cold took place subsequently to the elevation of the country above the Glacial sea.

IV. The Denudation-beds and Denudation-features of Yorkshire and Lincolnshire.

The denuded westerly edge of the purple clay on the Wold-top is occupied by thick masses of sand and gravel, which, near Speeton, pass over the edge of the clay. These, especially towards their base, although they rest extensively on the chalk, are principally composed of fragments of older Secondary, Palæozoic, and Metamorphic rocks, derived from the destruction of the purple clay, and containing very little of the material (the chalk) on which they rest, notwithstanding that this chalk rises towards the north-western angle of the Wold to nearly twice the height, where the greatest quantity of these sands occur. Setting in near Speeton and Reighton, they occur in numerous mounds of considerable depth and extent along the Wold-top there, and at Hunmanby New Mill. Thence, away towards the north-western angle of the Wold, they are scattered in a few places along its summit. A mass 50 feet thick, resting, we believe, on the purple clay, occurs under Speeton Mill, at an elevation of 457 feet. Another patch, some few square furlongs in extent, occurs at the north-west angle of the Wolds, at Thixendale Grange, at an elevation of about 700 feet, while others exist at elevations of about 600 feet, at Fimber and Huggate *. These appear to be the earliest deposits, in this part, of the Postglacial or general denudation-sea. Another extensive series of sands, with gravel, occurs along the Wold-foot from near Muston, through the great valley, as far as Malton, which, at East Flotmanby (near Muston) was found, in boring, to be upwards of 60 feet thick, with an unknown depth of shingle beneath. These Wold-foot sands, with gravel, are composed principally of local materials, Cretaceous and Oolitic, and, not having been formed until after the emergence and denudation of the Wolds, are thus newer than the sands on the Wold-top †. As we do not discover any traces of the Hessle clay along the *north* foot of the Wold, it might be inferred that its waters never penetrated the vale of Pickering; nevertheless the considerable elevation which that clay attains along the eastern slope of the Wolds, and especially at Swanland, three miles north-west, and at Melton Ross, ten miles south of Hessle, renders it difficult to suppose that this vale could have escaped being penetrated by the Hessle-clay waters through the gorge at Hutton, near Malton, and over the lower part of the ground around that place. In such a case it would seem to follow that these north Wold-foot gravels are of an age posterior to the sweeping out of the Hessle clay from that trough, unless they be,

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* The patch at Huggate rests on the only outlier of the purple clay that we have been able to detect over the high Wolds, with the exception of a small one at Fimber; so complete has been the denudation there. This outlier, however, at so great an elevation, satisfactorily proves the original envelopment of the Wold in the purple clay. We are under obligations to Mr. Mortimer, of Fimber, for the knowledge of the existence of these outliers.

† Although this appears to us to be a legitimate inference in this case, we are far from admitting that, as a general rule, levels are to be taken as evidence of the relative ages of Postglacial deposits, or that anything answering to general high- and low-level gravel-periods ever existed.

as is possible, the equivalents of that clay due to the different physical conditions obtaining within this enclosed area.   It is, however, not unlikely that gravels of more than one Postglacial age are included among the beds along this foot of the Wold.

The beds west of the Wold-scarp (which are principally gravels composed entirely of local materials) are developed at Cadney, Wrawby, Barnetby, and Brigg *, in Lincolnshire, and at Brough Cave, Hotham, and Market Weighton, in Yorkshire ; and they occupy the valley below the western scarp in places where the Hessle clay must (from its position in the Humber gorge, and at the considerable elevations just referred to) have once existed.   As there is no reason for supposing these to form any part of the Hessle gravel (*d*), left exposed here by the removal of the Hessle clay, there seems no alternative, to our apprehension, than to refer them to the period subsequent to the sweeping out of that clay along the western Wold-foot. They appear thus to be very nearly identical in age with the beds *f* of the coast-section (fig. 1); but whether they be of marine or fluviatile origin we have found no fossil evidence to show †.

In fig. 6 (*ante,* p. 161), which gives a condensed view of the denudation features of central Lincolnshire, we meet with a similar increase of denudation in the westerly direction, and see the Oolitic ridge, or " cliff," as it rises from the Langworth, become entirely bare of the Glacial clay.   Comparing that section with fig. 5, we see the same ridge equally denuded, with the added condition of all the Glacial clay between it and the Wold, which is present in fig. 6, swept away.   Now a similar series of sands to those occurring on the Wold-top, save that their constituent material differs, occupies the Lincolnshire Oolitic ridge ; and as the one starts from the denuded edge of the purple clay, so does the other start from the denuded western edge of the Glacial clay of mid-Lincolnshire, touching and, in places, slightly overlapping it.   Commencing north of Lincoln, at Welton, these sands stretch, past Spridlington, Normanby, and Glentham, towards Waddingham. After a short interval of omission, they begin again at Manton, and swell out into ridges and dunes, which occupy the summit of the " cliff," and near the latter place appear also to envelope it. Stretching thence northward to within a few miles of the Humber, these beds cover the ironfield of North Lincolnshire, and form extensive warrens near Manton, Bottesford, and Froddingham, reaching in that part nearly to the edge of the outlier of Glacial clay near Blyton, which is intersected by fig. 5.   A continuation of these beds seems also to occupy the Liassic escarpment at several places along the brow of the Trent valley, and near the confluence of that river with the Humber at Whitton ; but, not dealing with the structure of that valley in this paper, we need not refer to them further.   The position of these beds, where they crown the Oolitic ridge, has a special interest that can be best understood by the following section.

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* Those at Brigg are shown in fig. 5, under the symbol *x*.

† Some of them, however, contain derivative fossils, the gravels on the north side of North Cave abounding with remains from the Posidonomya-bed, and those on the south of it with *Gryphæa incurva.*

Fig. 12.—*Section of the " Cliff " at Redding's Wood, two miles east of Appleby.*

1. The Lias.   2. The Lower Oolite.   *x.* Denudation-beds, consisting of 10 feet of red sand overlain by 30 feet of rounded Oolitic gravel.   Height of the " cliff " (as ascertained by a bore carried down from the gravel half a mile east of the " cliff ") about 250 feet.   The steepness of the scarp is much exaggerated.

Notwithstanding that the position of the Glacial clay near Blyton, in fig. 5, seems to involve the assumption that the " cliff " existed as a ridge in the Glacial sea, yet the foregoing section shows that the present state of the scarp of that ridge has been produced by the Post-glacial denudation.   If the position of the gravel thus capping the " cliff " in fig. 12 be compared with that occupied by the Upper Glacial clay both east and west of the " cliff " in fig. 5, and east of it in fig. 6, and if it be remembered that this clay to the southward, at Ponton (in fig. 4), and to the northward, at Speeton (in fig. 1), occurs at elevations twice as great as that of the cliff itself (not to mention the obstacle presented by the cliff-ridge to the transmission of the chalk débris, were it out of the water), the inference that this ridge was enveloped by that clay appears to us unavoidable.   Its subsequent denudation, and the Postglacial age of the sands and gravels which occupy it, necessarily follow, as the whole structure of the region under consideration negatives the probability of any of these deposits belonging to the Middle Glacial series, left bare by the denudation of the Upper Glacial clay.   The latter part of this inference, however, is rendered unnecessary where these sands and gravels, leaving the summit of the ridge, touch and rest on the edge of patches of the Glacial clay, as they do more to the southward by Glentham and Spridlington.   The southern edge of the mid-Lincolnshire Glacial-clay tract is also occupied by a considerable sheet of gravelly sand, which covers the country between Tattershall and Horncastle for a considerable breadth, and has its northern boundary by Edlington Moor, Roughton, and Wood Enderby, mostly resting on the Oolitic clay, but at Roughton passing a little over the Glacial clay.   It enters and occupies the bottom of the Bain valley as far up as Horncastle, but in so small a degree that, in the absence of any evidence pointing to its being a river-valley gravel, we may regard it as belonging to the marine denudation-beds of the early Postglacial period.   A gravel of similar age occurs on the opposite side of the narrow arm of the fen that runs up to Lincoln, namely, near Metheringham.   This touches, and appears to rest slightly on, the Glacial-clay outlier of Timberland.   There is another deposit which skirts this fen-arm, consisting of a sandy warp-clay, and found by us to be about 9 feet thick, near Langworth village, and at Nocton

(places respectively north-east and south-west of Lincoln); but it seems to us to be of recent origin, and unconnected with the beds of the denudation-series.

Respecting the later Postglacial or scarp-augmenting part of the denudation which has operated on the Lincolnshire area north of Castor, we would refer again to the sections, figs. 7 & 8, at page 402 of the paper of the first-named of us, in the 23rd volume of this Journal. These cross the great troughs within which, after the crests of the chalk country of Hertfordshire and Cambridgeshire had emerged and undergone denudation (much in the same way as the Wold-crest has), the Postglacial sea had become confined, and wherein it eroded the chalk along which it swept. A comparison of these two sections with fig. 6 of our paper shows, we think, that if, instead of receding from mid-Lincolnshire after it had formed the valleys of that part by its earlier denudation, this sea had continued to erode so as to sweep out the Glacial clay and subjacent beds which are included within the broken line of our section, a section similar to that of fig. 8, in the 23rd volume, would have resulted. Further, if this erosion, instead of acting precisely thus, and forming a trough of which one side was chalk and the other Glacial clay, as in the last-mentioned section, had swept away the whole body of the Glacial clay lying between the eastern slope of the Oolitic ridge (or "cliff") and the Wold, we should get exactly the features displayed by Lincolnshire north of Castor, and illustrated by part of our section, fig. 5. Now, *wherever this has taken place, there the continuous scarp of the chalk Wold extends; but wherever it has not, there the chalk is not thus scarped,* but runs out into those ridges formed of Chalk, Subcretaceous beds, and Glacial clay together, or of the latter alone, both parallel with, and transverse to the Wold-strike, or forms one of the sides of the Steeping trough described in the previous part of this paper, and illustrated by figs. 6, 7, 8, 9, 10, and 11. If the Ordnance map be examined it will be seen that these features begin a little south of Castor, and so continue southwards to the Fen-border. It therefore appears to us that, just to Castor, and no further, reached the tongue of the later Postglacial sea which first swept out the Glacial clay, and subsequently, after the interval giving rise to the Hessle-clay deposit, swept out that clay also along the west of the Wolds.

Precisely similar features of denudation to those presented by the western Wold-foot are, with the exception of the existence of these denudation-sands, exhibited by the trough that runs along the north Wold-foot as far as Hunmanby. At this place a narrow belt of purple clay skirting the sea still fills the head of the trough, as shown at the extremity of fig. 1, completely barring it in from the area occupied by the present sea; so that the Hertford (an affluent of the Derwent, which flows away from the sea westward along this trough to Malton, and thence southward through the great depression into the Humber) is fed by brooks taking their rise close to the sea in this belt *. We have thus in this part the same barrier to the fur-

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* See the part marked † in fig. 1.

ther progress of an arm of the denuding Postglacial sea when, by the emergence of the land, it had sunk into those troughs after its earlier denudation (or that over the crests and that forming the general valley-system) had been accomplished, which is presented by the tract of Glacial clay still occupying the mid-Lincolnshire depression. Nothing shows so readily to an observer how little our present seas represent those of the Postglacial period than to view from the Wold-top above Speeton the sea close at hand on the east, and barred out in this way by the purple clay from the troughs occupied by the Postglacial sea, and to realize in a *coup d'œil* the grand westerly sweep of denudation which the latter sea has effected.

It is the mapping of the Glacial beds that best brings out these features and makes them intelligible ; but with that before us, though only in the more general way that we have been able to accomplish it, we see that the Glacial clay at Rasen (in mid-Lincolnshire) and that below Speeton, sixty miles apart, are respectively the points where terminated two separate tongues that parted from the larger arm of the Postglacial sea which occupied the great vale of York, and in which the outlying ridges of purple clay at Gate Helmsley, Flaxton, and Barton Hill before mentioned formed islands or shoals. The connexion of this larger arm with the main sea is more difficult to trace ; but as the other arms stretching southward, such as that which occupied the trough through which the Trent and upper waters of the Witham now run, seem barred in from the south by the great tracts of Glacial clay that stretch from near Corby, in South Lincolnshire, across Leicestershire into North Warwickshire, it would seem to be northward, in the direction of the Tees, that we should seek its outlet. Not, however, having examined the country northwest of York, we forbear to speculate upon the precise direction in which these arms of the Postglacial sea had their outlet to the main waters.

It only remains now to point out the distinction between the valleys north of Flamborough Head and those of the country south of it. Although the position of the Glacial beds shows that the Glacial sea occupied great depressions, such as that of Lincolnshire, traversed by the section, fig. 6, as that of the great vale of York, or as that on the north of the high chalk country of Hertfordshire and Bedfordshire*, yet wherever the Glacial beds by remaining furnish direct means of proof, we see that the valleys (as distinguished from the great scarped depressions) are wholly newer than those beds everywhere south of Flamborough, the only exception known to us being the long dry valley through which the railway runs from Hitchin by Stevenage and Welwyn† ; so that, although we must naturally

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* This depression is indicated by the lower position occupied by the Glacial clay on the north-western sides of the sections, figs. 7 and 8 at page 402 of the 23rd vol. of this Journal.

† This intræglacial valley widens near Hertford, and becomes the plain out of which *two existing parallel valleys*, those of the rivers Lea and Miran, are excavated (see a paper lately read before the Society by Mr. Hughes). It was filled with the Middle Glacial beds, out of which these two river-valleys are in that part formed.

infer that the Præ- and Intræglacial country was furrowed by a valley-system of its own, the present valley-system of the south has but little connexion with that prior state of things, but is essentially of Postglacial origin.   To the north of Flamborough, however, the contrary structure prevails ; and we may find evidence of this in all directions, a series of conspicuous examples meeting us immediately north of that point along the coast towards Filey.

The cliffs of Glacial clay, moreover, which extend north from Filey along that part of the coast-section, instead of being, like those of the south, sections of a solid clay sheet, which can with no more justice than the older Tertiaries be called a superficial deposit, are but the face of a coat of the purple clay which envelops the ancient Oolitic ridge running from the moorlands out to Fileybrigg (which, as before observed, seems to have induced the direction of the erosion giving rise to the northern Wold-scarp), a similar coat covering the inland slope of the ridge, as shown in the following approximate section, fig. 13.   The coast, moreover, north of Flamborough intersects

Fig. 13.—*Section of Gristhorpe Cliff.*

1. Kelloway rock.   3. Calcareous grit.
2. Oxford clay.   c. Purple clay.
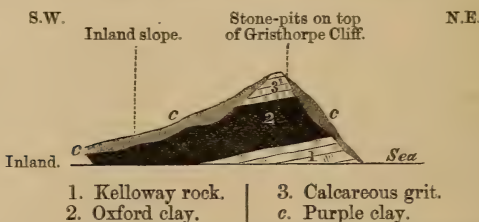
This section is intended to represent Gristhorpe Cliff intersected at right angles to its sea-face.   The beds 1, 2, and 3, free from any facing of *c*, present a mural precipice in the cliff a short distance from this point.

deep valleys, and shows them filled with the purple clay and partially reexcavated * ; so that what forms an extremely rare exception in the country south of Flamborough, becomes the rule north of it.

In conclusion, we should mention that, although the extreme west of Lincolnshire falls within the title of this paper, we do not here intend to describe it, except at the parts touched by figs. 4 and 5. This part may be more conveniently considered in connexion with the structure of the great valley of the Trent.

We desire to express our obligations to E. H. Clarke, Esq., the Engineer of the Grimsby Docks, and to W. Allen, Esq., the late Engineer of the Hull West Docks, for much valuable information and assistance.   Our thanks are also due to T. Dale, Esq., the Engineer of the Hull Waterworks, to A. Atkinson, Esq., the Engineer of the Ancholme Navigation, to George Simpson, Esq., of North Burton,

* Strictly speaking. two of these valleys, by crossing the Cape of Flamborough, come out also immediately on the south side between the Head and Bridlington, and are filled with beds of hard chalk débris below the purple clay.   See South Sea and Danes Dyke in fig. 1.

to J. A. Wade, Esq., of Hornsea, and other gentlemen, for information supplied, and for assistance in our investigations.

V. Appendix.

In the course of our examination of the district we collected a considerable number of borings, with the idea that they would speak for themselves. The similarity, however, in the lithological character of most of the beds, although of no moment in the coast-section (fig. 1), becomes, in borings, a source of confusion. It therefore appears to us that to give these borings in detail would not be attended with any advantage commensurate with the space they would occupy; and we merely propose briefly to epitomize their results, as far as we have been able to put a satisfactory interpretation on the particulars recorded.

As shown in figs. 5, 8, and 11, the Hessle clay overlaps the purple clay on the east of the Wold. Between Hessle (where that clay with its gravel rests direct on the chalk, and where the latter rises considerably above the Humber) and Hull, we have a boring at Dairycoates which shows the Hessle beds only over the chalk, the purple clay (which is tolerably thick at Hull) having thinned out at this place, which is one mile west of Hull *. At Hull a series of 29 borings along the river-front, preliminary to the dock-excavation, disclosed the existence of the purple clay underlain by a sand- and gravel-bed, answering to " b " of the coast-section (fig. 1), the chalk-floor being at a depth of 103 feet below highwater-mark. Several other borings in, and immediately around, Hull disclose the same sand and gravel, but of very irregular thickness; they also show the purple clay thinning off and disappearing towards the north of the town, and the rise of the chalk there to within 50 feet of the surface. Two miles north-east of Hull, however, at Sutton, the chalk is 105 feet from the surface. The dock-borings at Hull work out into the subjoined resulting section (fig. 14, p. 182).

Two borings at Sunk Island gave the chalk at a depth of 112 and 113 feet respectively, passing in their upper parts, in the one case, through 58, and in the other through 34 feet of recent deposits, then through a thickness of red and brown clay with some chalk, answering to the base of the purple clay, then through the beds (b) of the coast-section (fig. 1), and, finally, through a small thickness of the basement clay (a), in the one case through 5, and in the other through

* The boring is as follows :—

	feet.	ins.
Warp	20	0
Peat	2	0
Clay with small checkers (Hessle clay) ...	19	6
Sand with small shells (Hessle sand)	12	6
Chalk at	54	0

The clay with small checkers answers exactly to the character of the Hessle clay. The shells in the sand were not seen by us; but the gravel at Paull and at Kilnsea, which we regard as the Hessle sand, is fossiliferous.

10 feet of it.   Unless there be any great rise of the chalk-floor east-
wards, towards Kilnsea and Dimlington, these borings would show
that the chalk at the latter places was upwards of 100 feet below the
beach.   In that case the thickness of the basement clay exposed at
Dimlington (beneath nearly 100 feet of the purple clay) would, added
to this depth, give a total thickness of about 120 feet for the thickness
of the basement clay in that part*.   A similar uniformity in the
depth of the chalk-floor seems to be maintained along a line running
due east from Hull to Withernsea, as shown by three borings into
the chalk near Hedon, and by the borings along the Withernsea
Railway, given by Mr. Prestwich †, which, although not reaching the
chalk, showed 82 feet of deposits at Withernsea, a spot but little

Fig. 14.—*Section constructed from the borings for the Hull Docks.*
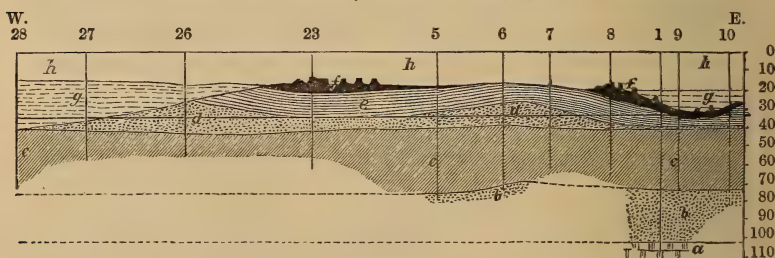
a. Chalk.   b. Sand with chalk-rubble (bed b of coast-section, fig. 1).   c. The Purple clay,
   called in the borings "Brown stony clay with sand threads."   d. The Hessle sand.
   e. The Hessle clay.   f. Peat-bed with the stools of trees rooted into it and into e,
   and with the stems lying flat in the peat.   g. Silt abounding with *Tellina solidula*,
   Scrobicularia piperata, *Cardium edule*, &c.   h. Salt water.   The length of the sec-
   tion is about one mile, the vertical scale being about eleven times the horizontal.
   The numbers along the top denote the borings as numbered in the Dock Engineers'
   record, being such of the borings as (with the exception of 1 and 5) run in a con-
   tinuous line, about 80 yards from the shore.   Nos. 1 and 5 being out of that line
   and nearer the shore, the depth of the water (h) is in their case disregarded.   The
   vertical numbers denote the depth below the datum line, which is that of high
   water.   The broken lines indicate the presumed continuation of the beds where the
   borings do not descend to them.   The portion of the section above the horizontal
   line between the 30 and 40 feet mark is that which was fully exposed during the
   subsequent excavations; but the excavations were in some parts carried deeper,
   and into the purple clay (c).

above the beach.   Several borings at Hornsea gave, after deducting
the elevations of the places, the chalk at a depth of from 60 to 70 feet
below the sea-level.   This, when the thickness of the basement
clay exposed in the cliffs north and south of this place is added,
would show that clay reduced at least one-third in thickness to that
possessed by it (on the assumption before made) at Dimlington.   A
boring at the New Inn, Hornsea, gave the chalk at a depth of 161

* As shown in fig. 11, however, there is probably some upheaval in this
part which would involve a less depth for the chalk-floor, and consequently a
less thickness for the basement clay.
† Quart. Journ. Geol. Soc. vol. xvii. p. 455.

feet, passing through gravel all the way (the upper 60 feet yielding small shells); this would, if the boring be reliable, seem to show that the trough containing the fluviatile fossiliferous gravel of that place (f in fig. 1) descends to that depth, cutting through the Glacial clay for some distance into the chalk.   A boring at Rise, five miles south-west of Hornsea, reached the chalk at 128 feet, which, by deducting the elevation given on the Ordnance map for Rise, would show the chalk at that place to be at about the same depth as at Hornsea.   From Hornsea towards Bridlington a gradual rise in the chalk-floor probably takes place, accompanied by a thinning-off of the basement clay and an overlap of the purple clay, since, north of Atwick, the basement clay, notwithstanding the rise of the floor, is no more seen.   The boring at Bridlington Harbour, given by Young and Bird, showed the chalk at a depth of 43 feet, the upper 28 of which was occupied by clay, and the rest by a bed of gravel resting on the chalk.   There can, we think, be no question that this 28 feet of clay is part of the purple clay, and the gravel the bed b of the coast-section (fig. 1), since the purple clay shows itself resting on the chalk as the latter gradually rises above the beach north of the harbour. The so-called Crag having been found, and still occasionally being exposed, at the beach-line, it is necessarily superior to this 43 feet of deposits.

Although the borings at Hull, Grimsby, Cleethorpe, and Bridlington disclose a bed of sand and gravel between the purple clay and the chalk (answering, as it seems to us, to the bed b of fig. 1), none of the borings through the basement clay show anything between that deposit and the chalk, except one (out of three) at Hornsea, which showed 5 feet of sand beneath it.   There is nothing, therefore, yet disclosed in Holderness which we could refer to any older deposits than the Upper Glacial clay; and nothing that would answer to the extensive Middle Glacial sand and gravel formation which underlies so much of the Upper Glacial clay of the counties of Leicester, Buckingham, Hertford, Essex, Suffolk, and Norfolk.

The result of the Grimsby-Dock borings, as worked out into resulting sections by the Dock Engineers, being referred to in the body of the paper (page 157), it is unnecessary to repeat them here.   They showed numerous intermittent beds of gravel, answering to those marked c' in fig. 1, intercalated in the purple clay, the latter sometimes resting directly on the chalk and being sometimes underlain by gravels which seem to answer nearer to the bed b of fig. 1 than to any other.   No trace of the basement clay existed, although the chalk was reached in many of the borings.

At Cleethorpe, two miles from Grimsby, a boring showed 84 feet of red and purple clay over the chalk (nothing like the basement clay being present); and as the Hessle clay, 10 or 12 feet thick, caps the purple clay in the cliff hard by, there is no doubt that the upper 10 or 12 feet of this belonged to that clay—a sand-bed occurred in it at far too great a depth to be referable to the Hessle sand, and is therefore a similar intercalated (c') bed to those passed through at Grimsby.

At Burgh, near the southern extremity of the Wold, we are informed by Mr. J. W. Judd, F.G.S., that several borings in the marsh showed Boulder-clay to be present, but extending to very unequal depths; all of it appears to be the lead-coloured clay with a profusion of chalk, and to answer to the basement clay of Holderness and the ordinary Upper Glacial clay, which begins a few miles west of this place and has a considerable extension over Central and South Lincolnshire.

It may be useful to those studying the Cretaceous formations to add that a boring carried through the chalk at Hull into the blue Oolitic clay gave 536 feet for the thickness of this formation there; while at Hornsea, a boring, after passing through 797 feet of it, failed to pierce the chalk, some bands, described in the boring as "fuller's earth," alternating with chalk in the lower part of the boring. A band of red chalk occurred in the white chalk a few feet from the surface of that formation in one of the Grimsby-Dock borings.

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JANUARY 8, 1868.

Francis Fedden, Esq., Geological Survey of India; Major Sir George Wingate, K.C.S.I., J.P., late of the Bombay Engineers, Crofton, Hants; and John Baldry Redman, M.I.C.E., 6 Westminster Chambers, Victoria Street, S.W., were elected Fellows.

The following communications were read:—

1. *Notes on the* LOWER-LIAS BEDS *of* BRISTOL.
By W. W. STODDART, Esq., F.G.S.

THE occurrence of beds in the Bristol district corresponding to the Sutton beds of Glamorganshire has been thought worth noting.

In this locality the sequence of the different groups of strata is so perfect that the position of any one of them becomes almost a matter of certainty.

In many places the beds are apparently so bare of organic remains, that the collector is at once discouraged. The very horizontality of the beds themselves is frequently an obstacle, from the great distance to be walked over before a change of zone takes place.

The line of section in the following sketch (fig. 1) runs from a quarry (No. 1) north of the Orphan House on Ashley Down, across Montpelier, to Cotham Hill.

As shown in the figure, three quarries, now fortunately opened, explain the whole series of beds contained in the section.

It will be seen that the series extends from the base of the zone of *Ammonites Turneri* down to the Rhætic beds.

All of them dip 8°, to the north-east. This small angle makes the beds appear nearly horizontal, and at first sight makes their order very puzzling.

It is rather singular that the strata here should dip north-east
while those on the opposite side of the Severn dip to the south-
east.   It shows an anticlinal to exist somewhere to the south of

Fig. 1.—*Section from Ashley Down to Cotham.*
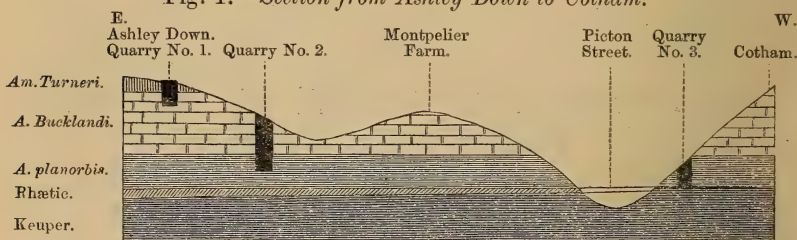
that river. The rising of the land must of course be very gradual, but
quite sufficient to form a shallow trough from the neighbourhood of
Gloucester towards the British Channel—an idea confirmed also by
the observations in the Gloucestershire collieries below the surface,
and by the denudation that has evidently taken place above it.
The latter especially shows a very strong current to have existed
ever since the Triassic period, running from north-east to south-
west.   The edges of the strata, where they crop out of the hill-sides,
show very plainly that many miles of deposits that formerly existed
between the Silurian and Oolitic shores must have been washed
away.

Starting, then, from Ashley Down, we commence with what is
now exposed of the *Ammonites-Turneri* and *A.-Bucklandi* zones.

Fig. 2.—*Section of No. 1 Quarry, Ashley Down.*
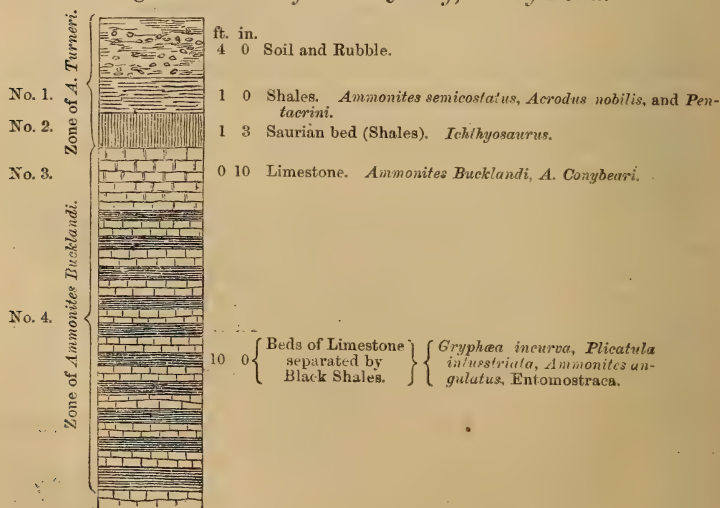
1. *Ammonites-semicostatus Bed.*—There is here only 1 foot of dark shale between two thin beds of limestone, containing many crushed specimens of *A. semicostatus* (Y. and B.), mixed with a few joints of *Pentacrini*.

A little further on, these beds yield *A. Sauzeanus, Acrodus nobilis,* &c. in abundance.

2. *Saurian Bed.*—This bed contains a great number of the vertebræ and bones of *Ichthyosaurus* and *Plesiosaurus*, with occasionally a *Nautilus*.

3. *Conybeari-bed.*—A bed of hard limestone, lying immediately below No. 2. On its upper surface specimens of *A. Bucklandi* and *A. Conybeari* lie in great numbers.

I consider this to be the beginning of the *A.-Bucklandi* zone.

Underneath this bed, *Nautili* occur in good condition.

4. *Lima-beds.*—These are a series of very blue argillaceous limestone beds, divided by dark shales. Their average composition is 90 per cent. carbonate of lime, 6 of sulphate of lime, and 4 of silica, alumina, and oxide of iron.

The upper twelve beds contain immense quantities of *Gryphœa incurva*, sometimes in nests of 40 or 50 valves. *Plicatula intusstriata*, Emmerich, is also abundant. I have a specimen of *Gryphœa* with five *Plicatulœ* upon it. The *Plicatula intusstriata* exactly corresponds with Moore's figure, pl. 16. fig. 25, both in size and markings.

With them occur plentifully *Ammonites angulatus*, Schloth., or at least portions ; for a perfect shell is hardly ever found.

From these beds also are collected *Pleurotomaria Anglica, Pholadomya glabra, Lima pectinoides, Pecten textorius, Rhynchonella variabilis,* and some small species of *Chemnitzia*.

The succeeding beds are covered up for a short distance, and then we come to

5. *Ammonites-torus Bed.*—About four feet below the surface of this quarry occurs a bed of limestone, containing *A. torus* and *A. tortilis* of D'Orbigny.

With them are also scales of *Pholidophorus nitidus*. They are, however, more plentiful in a ferruginous bed just below, associated with those of *Gyrolepis Alberti*.

6. *Echinoderm-beds.*—These, the most interesting beds of the whole quarry, are full of the spines and jaws of *Cidaris Edwardsi*, and spines of *Hemipedina Bechei*. The little jaws are very abundant. They are preserved in most perfect condition, showing the striated side and crenated edge, like those of the recent *Echinus miliaris*.

With them are multitudes of beautiful little *Cytheridœ*, a few Foraminifera, small teeth, and shell-débris.

All these are to be collected in any quantitiy ; and as these beds extend for miles, the profusion of Echinoderms must have been astonishingly great when these strata were deposited.

7. *Johnstoni-beds.* — There are 29 beds, chiefly consisting of fissile, slaty, very argillaceous sandstones and limestones. The specimens of *Ammonites Johnstoni* are very abundant and large.

The shells have disappeared, leaving very perfect casts.   Under these is the

8. *Avicula-bed.*—This remarkable deposit forms the bottom of the quarry; for the workmen do not find it pay to go lower, on account of the expense of blasting the limestone-bed beneath.

Fig. 3.— *Montpelier Quarry.*

		ft.	in.		
No. 5.	Zone of A. Bucklandi.	11	4	Shales, clays, and lime-stone (9 beds).	Fish-scales, *Lima gigan-tea*, *Am. torus*.
No. 6.		3	0	Clays and limestones (4 beds).	Fish-scales abundant.
		2	0	Sandy clay	Jaws and spines of *Echini* very plentiful, and also *Cytheridæ*.
No. 7.	Zone of Ammo-nites Planorbis.	17	2	Shaly beds, &c (29 beds).	*A. Johnstoni*, *A. tortilis*.
No. 8.		0	4	Hardened clay..............	*Avicula cygnipes*, Sau-rians, *Ostreæ*, *Pecten*, spines, &c.

When well exposed, this bed is very interesting to the palæontologist.   Specimens of the fine *Avicula cygnipes*, with the shell preserved, lie about in every direction, sometimes 12 or 14 in a square yard, intermingled with saurian vertebræ, *Ostreæ*, *Pecten*, and *Echinus*-spines; indeed the bed is made up entirely of animal remains.

It is, however, the succeeding beds which the author hopes may help to settle the position of the Bridgend series.

They present very decided evidence in favour of Mr. Bristow's opinion of its being far above the Rhætic beds, and in the Planorbis-zone.

From the following section it will be seen that the typical Planorbis-fossils occur both above and below the Sutton fossils; and both are four feet *above* the well-known Cotham marble, which in the Bristol district is always known to be immediately above the *Avicula-contorta* series.

Unless, with Mr. Moore, we include the White Lias with the Rhætic

formation, the latter is absent from the Cotham quarry, because, so far as I know, the Keuper marls immediately underlie the Cotham marble.

The Glamorganshire beds, it is true, differ in their conglomeratic condition ; but that is evidently owing to their geographical position.

Mr. Etheridge and Mr. Sanders have both examined the spot. Their intimate knowledge of the geology of the Bristol district must go very far towards establishing the opinion that the Sutton series belongs to the Planorbis-zone.

Fig. 4.—*Cotham Quarry.*

		ft.	in.		
No. 9.		2	6	Rubble........................	*Am. planorbis, Lima Dunravenensis.*
		0	4	Purplish clay.	
No. 10.		0	6	Limestone	*A. tortilis.*
No. 11.		6	0	11 Blue limestone beds alternating with clays. Sutton series.	*Lima Dunravensis. Lima tuberculata Pecten Suttonensis. Pinna insignis. Ostrea multicostata. Cardenia Suttonensis.*
No. 12.		0	9	Blue conchoidal limestone.	Fish-scales and elytra.
No. 13.		2	0	Limestones and shales with clay partings.	*A. Johnstoni.*
No. 14.		2	0	Thin beds of White Lias.	*Modiola minima, Myacites, Monotis,* &c.
No. 15.		0	4	Cotham landscape-stone.	

9. *Rubble Bed.*—This, which underlies the soil, contains a considerable number of very good specimens of *Ammonites planorbis*. In the same bed are *Lima gigantea* and *Lima Dunravenensis*. The last agrees exactly with Mr. Tawney's fossil by differing from *L. gigantea* in having well-marked ribs, and from *L. punctata*, which it greatly resembles, by having slight rugæ instead of the well-known punctate markings.

Under an intervening 4-inch seam of clay is

10. *Tortilis-bed.*—This is only interesting as denoting its geological position by containing *Ammonites tortilis*, D'Orb.

11. *Sutton Beds.*—As described in the section, these are eleven beds of limestone, alternating with clays.   The sixth from the top

is the most prolific in fossils. Of these, *Lima tuberculata*, *L. Dunravenensis* and *L. gigantea* are the most common.

The whole of these beds are full of *Ostrea liassica*.

Immediately under the 11th bed is

12. *Pholidophorus-bed.*—This is a blue conchoidal limestone, well known as containing the elytra of beetles and several species of *Pholidophorus*.

13. *Johnstoni-beds.*—These are shaly limestones, containing *Ammonites Johnstoni*, and from that circumstance are worthy of mark.

14. *White Lias.*—On this hill the White-Lias beds are very insignificant, being only two feet thick They contain, however, an abundant supply of *Modiola minima*, *Monotis decussata*, *Myacites*, &c.

Although thin, these beds are very well marked, and lie just above the

15. *Cotham Marble.*—This is perhaps better known as the landscape stone, having markings of manganese resembling trees, &c., and is sold for ornamental purposes.

This last bed rests upon the Keuper marls, which here attain a pretty good thickness.

As before mentioned, the *Avicula-contorta* beds of the Rhætic series are here absent, although so well developed a few miles off at Almondsbury, where, singularly enough, the Cotham marble thins out as the Rhætic beds thicken and increase.

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2. *On the* LOWER-LIAS BEDS *occurring at* COTHAM, BEDMINSTER, *and* KEYNSHAM, *near* BRISTOL. By C. O. GROOM-NAPIER, Esq., F.G.S.

(Abstract.)

The author first describes two quarries at Cotham exhibiting the following sections :—

I. *Quarry at the back of Dundry Villa.*

		ft.	in.		ft.	in.
1.	Soil ....from	0	10	to	1	2
2.	Argillaceous loam	0	10	to	1	2
3.	Shaly limestone containing *Cypris liassica* and *Chondrites liassinus*..................................	1	3	to	1	
4.	Pale-blue limestone containing casts of *Littorina*, *Lima punctata*, &c...............................				6	0
5.	Ferruginous sandy Lias (Planorbis-bed) containing abundantly *Ammonites planorbis*, and less commonly *A. Johnstoni*; also *A. tortilis*, *A. torus*, *Solarium lenticulare*, *Turbo subelegans*, *Cerithium Semele*, *Pleuromya liassina*, *Cidaris Edwardsi*, *Pecten calvus*, *Ostrea liassica*, *Lima succincta*, *L. tuberculata*, *L. acuticostata*, *L. Hettangiensis*, *L. exaltata*, *Avicula*, spec. nov., *Unicardium cardoides*, fragments of the bones of *Ichthyosaurus*, *Plesiosaurus*, and their teeth, rarely *Terebratula perforata*, *Mytilus minimus*, and *M. Hillanus*...................................	3	0	to	4	0
6.	Hard grey sandstone with quartz grains ....thickness unknown.					
7.	Clay	0	9	to	1	0

8. Friable conglomerate, containing casts of nearly all the shells found in No. 9.

9. Pale-blue thick-bedded Lias containing *Ammonites Johnstoni*, *Lima punctata*, *L. elevata*, *L. tuberculata*, *L. gigantea*, *L. acuticostata*, *L. duplum*, *L. subduplicata*, *L. Terquemi*, *Pholodomya prima*, *P. glabra*, *Pecten calvus*, *P. textorius*, *P. Suttonensis*, *P. quadricostatus*, *Perna infraliassina*, *P.* species, *Pleuromya unioides*, *P. Galathea*, *P. liassina*, *Unicardia cardioides*, *Cardinia Listeri*, *Ceromya gibbosa*, *Ostrea liassica*, *O. irregularis*, *Terquemia arietis*, *T. Heberti*, *Plicatula intusstriata*, *Mytilus minimus*, *M. Hillanus*, casts of a species of *Gervillia*, *Chemnitzia*, sp., *Axinus*, sp., *Astarte consobrina*, *A. thalassina*, and *Cidaris Edwardsi*. Near the bottom of this bed is the bone-bed of this series, about 4 inches thick. It contains scales of *Pholidophorus*, teeth of *Hybodus*, scales of *Gyrolepis tenuistriatus*, and *G. Alberti*, small coprolites of fish, and *Plicatula intusstriata*. The scales are mostly fragmentary and badly defined. A *Lima*, which I believe to be *L. punctata*, is the most characteristic shell of this bed.

10. A second Oyster-bed, abounding in *Ostrea liassica*, and with a few specimens of *Ammonites Johnstoni*   0   6

11. Clay with *Monotis decussata*, *Ostrea liassica*, *Perna infraliassina*, *Pleuromya unioides*, and *Cardium Philippianum*.   0   1 to 0   3

12. Laminated argillaceous limestone, sometimes almost entirely composed of *Mytilus minimus*, *Modiola Hillana*, *Cardinia Listeri*, *Pholadomya*, sp., and casts of Littorina.

13. Soft sandstone containing *Chondrites liassinus* with *Cypris liassica*, *Cardium Philippianum*, *Cucullæa Hettangiensis*, *Pleuromya*, sp., and *Pecten vimineus*.

14. Indurated dark-grey clay with crystals of sulphate of strontia and carbonate of lime.

15. Cotham marble.

16. Keuper marl; on the surface of this stratum the author found a single specimen of *Pecten* (*Valoniensis?*), and fragments of bones of *Ichthyosaurus* and *Plesiosaurus*.

II. *Quarry in a field about* 100 *yards from No.* I.

1. Vegetable soil   2   0
2. Argillaceous loam . . . .   0 10 to 1   2
3. Sandy limestone passing into blue marl, the latter yielding *Lima gigantea*, *Pholadomya glabra*, *Rhynchonella plicatissima*, and spines of *Cidaris Edwardsi*   0   9 to 1   0
4. Dark-blue compact limestone containing *Ammonites angulatus*, *Cidaris Edwardsi*, *Littorina semiornata*, *Pecten calvus*, *Gryphæa*, species, *Rhynchonella variabilis*, *Terebratula perforata*, *Ostrea irregularis*, *Pentacrinus Fisheri*, *Mytilus minimus*, *Modiola Hillana*, and fish-scales   1   0
5. Blue Limestone, alternating with clay, and containing *Lima gigantea*, *Ammonites planorbis*, *A. Johnstoni*, *Lima punctata*, *L. tuberculata*, *L. acuticostata*, *L. succincta*, *L. exaltata*, *Pecten Suttonensis*, *P. quadricostatus*, *Pleuromya unioides*, *P. Galathea*, *Ceromya gibbosa*, *Plicatula*, species, *Terebratula perforata*, *Hemipedium Bechii*, *Astarte consobrina*, fish-scales and traces of Saurian bones.   6   0
6. The Oyster-bed, which is separated from No. 5 by a narrow belt of blue clay; it contains *Ostrea liassica* in great numbers.
7. Conglomerate, containing the same fossils as bed No. 8 in the previous section.

8. Blue and cream-coloured limestone, containing most of the fossils found in bed No. 9 of the preceding section, as well as a similar bone-bed.
9. Sandy Lias, containing an abundance of *Ostrea liassica*, similar to bed No. 10 of Section I.
10. Equivalent to bed No. 11; but that corresponding to No. 12 is absent.
11. Dark-coloured clay with sulphate of strontia.
12. Cotham marble, containing *Ostrea irregularis* and *Mytilus minutus*.

Near the water-works on Bedminster Down, the uppermost beds resemble those of the Cotham sections; but the author had not found the Upper Plant-bed (No. 3 of Section I.). Bed No. 4, with its fossils, and No. 5, with *Ammonites planorbis* &c., are represented by less ferruginous and sandy beds. The fossils obtained, however, were less numerous than at Cotham. The lower beds were not well exposed.

Several quarries at Keynsham afford good sections: one, about a furlong from the village, exhibits the Bucklandi-series; a second, three-quarters of a mile from the village, shows the Planorbis-series and Cypris-beds, with *Lima gigantea*, *L. succincta*, *L. punctata*, *L. tuberculata*, casts of *Littorinæ*, &c.; and Hill's Quarry affords a section of the Planorbis-series and numerous belts of Lias.

The author comes to the conclusion that the Sutton stone is a Liassic rather than a Rhætic bed,—that the White Lias is represented by beds No. 2 to No. 11, inclusive, of Section No. I., while the Sutton series includes No. 6 to No. 12,—and that the Planorbis-zone and the Sutton series are subdivisions of the White Lias.

Mr. Groom-Napier then gives the following descriptions of three new species.

1. AVICULA SANDERSI, spec. nov.
Shell $1\frac{3}{16}$ inch long by $\frac{9}{16}$ in. broad; thin and flat, with one rib running diagonally across it. Surface smooth, subovate, with fine yet very clearly defined concentric lines of growth; umbones slightly curved outwards. Locality Planorbis-bed, Cotham. One specimen only. This I have named after my friend Mr. William Sanders, F.R.S., F.G.S., whose researches as a geologist, and whose map of the Bristol Coal-field, are so well known.

2. ANATINA COTHAMENSIS, spec. nov.
This shell is oval and pointed, $\frac{1}{2}$ an inch long by $\frac{1}{4}$ broad. Surface marked by fine curved striations, granulated at the posterior edge. I have found this solitary specimen in the Planorbis-bed, Cotham.

3. HINNITES MINUTUS, spec. nov.
This I believe to be new; shell coarsely striated, round; has 7 forked striations. Shell $\frac{7}{16}$ inch long by the same broad. Locality, first quarry, bed No. 11, accompanying *Monotis decussata*. I may mention that I have found a slab at Cotham containing *Pecten Helii*, *Rhynchonella plicatissima*, Quensted, and what is apparently *P. Valoniensis*; but not being found *in situ*, I have not mentioned it in my notes on the strata.

3. *On the* DENTITION *of* RHINOCEROS ETRUSCUS, Falc.   By W. BOYD
    DAWKINS, Esq., M.A., F.R.S., F.G.S.

[PLATES VII. & VIII.]

CONTENTS.

1. *Introduction.*—The dentition of three* of the fossil species of
Rhinoceros has already been defined, and there remains only that of
the fourth or Etruscan to complete the odontography of those mem-
bers of the genus that inhabited Britain during the Pleistocene
period.   Some years ago Dr. Falconer, along with M. Lartêt, had
detected in the collections of Mammalia from the Forest-bed, and
especially in that made by the Rev. John Gunn, teeth which clearly
were neither Megarhine nor Leptorhine.   Similar teeth he also found
in Italy and Spain, and from their abundance in the former country
he named the animal to which they belonged *Rhinoceros Etruscus.*
Unfortunately its description was prevented by his sudden death;
and the only authentic memorials consist of names attached to spe-
cimens in various museums, and of a few fragmentary notes which
were dictated to the Rev. S. W. King, and which are printed at the
feet of these pages†.   At the time of Dr. Falconer's death there
were not sufficient materials in Britain for an accurate specific deter-
mination; now, however, they are afforded by the entire molar series,
except the first premolar of the lower jaw, forwarded to me by the
kindness of the Rev. S. W. King, F.G.S.   Specimens from France
have also been sent me by M. Lartêt; and others have been discovered
in the British Museum.   I am therefore in a position to complete the
odontography of a species about which less is accurately known than
any other ranging through southern Europe.

2. *Dental Formula.*—The number of teeth possessed by *Rhinoceros
Etruscus* is the same as that of the three species already described;
it consists of

$$\text{Dm.} \frac{4}{4}, \quad \frac{\text{I.0} \quad \text{C.0} \quad \text{Pm.2.3.4.} \quad \text{M.1.2.3.}}{\text{I.0} \quad \text{C.0} \quad \text{Pm.2.3.4.} \quad \text{M.1.2.3.}}$$

The first premolar, if present at all, disappeared very early in life,
without leaving any trace behind—a point by which the animal may
be defined at once from all the Miocene species which have yet
been found.

3. *Permanent Upper Molar Dentition.*—Only two specimens of the
Etruscan milk-teeth have come before me :—the one a last lower
molar, in the possession of Mr. Fitch, of Norwich; the other, con-
sisting of the milk-molars 3 and 4, in a jaw belonging to the Rev.

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* Nat. Hist. Rev. 1863, No. XII. p. 525; Nat. Hist. Rev. 1865, No. XIX. p.
339; Quart. Journ. Geol. Soc. vol. xxiii. (1867), p. 213.

† Since this paper was written (October 1867), Dr. Falconer's Memoirs have
been published (January 1868), in which all the memoranda bearing on the
species in his note-books are given. (Vol. ii. p. 354 *et seq.*)

S. W. King. The jaw in which the former of these is implanted is described by Dr. Falconer*. These two specimens afford insufficient data for describing the milk-molars ; and therefore I will pass on at once to the true molar series.

The upper true molars of *Rhinoceros Etruscus* are defined at sight from those of any other British species by the lowness of their crowns, the abruptly tapering form of the colles †, *d* and *e*, and the stoutness of the guard, *o*, on the anterior aspect. The grinding-surface of the crown is deeply excavated, as in the Leptorhine and Megarhine teeth, instead of being worn flat, as in the Tichorhine ; and the enamel is remarkable for its smoothness. For the British type of the species I have chosen the molar series found in the Forest-bed at Pakefield (Pls. VII. figs. 1, 2, and VIII. fig. 4), in which all the teeth are present except the first premolar of the lower jaw. It belonged to a Rhinoceros rather past the meridian of life. It is covered with a red ferruginous matrix, locally termed " pan," which is character-istic of fossils which have been imbedded in the Præglacial deposits of the east coast. The first of the premolars (Pl. VII. figs. 1, 2) is remarkable for the stoutness of the guard, *o*, that runs round the anterior and inner surfaces of the crown, forming a clearly defined step from its passage round the median collis, *e*, to its upward sweep at the point on the anterior aspect where the anterior collis, *d*, joins the lamina. Its horizontal position up to that point is characteristic, and defines the tooth from any of its Pleistocene or recent homo-logues. Its antero-external angle is slightly produced. Costæ 1 and 2 are slightly developed, while costa 4, bounding the tumid posterior area, is sharp and well defined. The second premolar, pm. 3, re-produces all the characters of the first, excepting the production of the antero-external angle. It is very much larger, and presents an outline more nearly approaching an oblong. The tumidity also at the base of the posterior area, *n*, is more pronounced. The third premolar, pm. 4, is differentiated from the second only by its greater size. The horizontality of the guard, *o*, and its height above the cingulum, characterize the whole of the premolar series, and prevent its being confounded with that of any other British species. The

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* " *Rhinoceros* ——. Left ramus, lower jaw, five teeth out, last true molar not protruding, last milk-molar not dropped out, showing symphysis and dia-steme; longitudinal striæ well marked; matrix of 'red pan' of forest-bed well marked. Length from anterior end of socket of first premolar (dropped out) to end of last true molar 10 inches." (Dictated to the Rev. S. W. King by Dr. Falconer.) Dr. Falconer, however, seems to have made up his mind afterwards as to its Etruscan character. See Palæont. Memoirs, vol. ii. p. 347, published after this essay was written.

† A list of the terms and letters used to identify homologous parts in the teeth of Rhinoceros has already been given, in the Quart. Journ. Geol. Soc. vol. xxiii. p. 218. Without the use of some such system it is impossible to assign a true value to the differences observable between closely allied species of the same genus. Throughout the essays on the dentition of Rhinoceros, the same terms and letters are used, so that the homologous parts in any one tooth may be compared with those of any other. Most of the terms are taken from the masterly work on the Tichorhine Rhinoceros by Professor Brandt (Mém. Acad. St. Pétersb. 6ᵉ sér. tom. vii.).

height of the entrance of the anterior valley, a, above the cingulum, is also a point of difference. In this case it is worn away. There is but little difference observable between true molars 1 and 2. In both the guard is very strongly marked on the anterior aspect, and is represented, more or less, by a line of small obtusely pointed cusps passing across the anterior collis, d, and the posterior, e. In the first true molar it is not observable on the inner aspect of d, but it blocks up the entrance into the anterior valley, a; while in the second it is visible on the former and absent from the valley-entrance. In both it is present on the inner base of e. The entrance of the anterior valley, a, is wide, the posterior combing-plate, h, is very large. The third collis, e, is notched and cuspless, as in the Mega-rhine and Leptorhine teeth. The two anterior costæ, and especially the second, $k\,2$, are strongly marked; and the posterior area, n, is excavated, and inclines very much inwards as it approaches the grinding-surface of the crown; at the point, however, where it joins the cingulum it is tumid. A ridge sweeps round the bottom of the laminæ, and connects costa 1 with costa 4. These last two points are highly characteristic. The last true molar (Pl. VIII. fig. 4), which is about half worn, is remarkable for the great width of its valley-entrance, and for the great development of the posterior combing-plate, h, which passes across the valley and is fused to the anterior collis, d, and thus insulates the head, c, of the anterior valley, a. The guard, o, is very stout on the anterior aspect of d, and is repre-sented by a line of cusps at the inner base of the latter. The pos-terior valley, b, is a faint depression behind the median collis, e, circumscribed by a cuspless ridge of enamel homologous with the third collis, f, in the upper molar series.

In the Rev. S. W. King's collection there are several isolated teeth belonging to the Etruscan species, and all obtained from the Forest-bed on the east coast. A right upper true molar 3[*] reproduces all the characters of that which has been just described. Two premolars also correspond exactly with the third premolar of the Pakefield jaw, while the third, or the first premolar (Pm. 2) of the right side, is remarkable for the development of an accessory combing-plate. Its posterior collis is notched and cuspless. The entrance of the anterior valley and the cingulum are situated respectively 0·82 and 0·48 inch from the base of the crown. Among the teeth of *Rhi-noceros* forwarded to me by the Rev. John Gunn, is a small right

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[*] *R. Etruscus*, Falc.; syn. *R. leptorhinus*, Cuv., pro parte, *R. tichorhinus* auc-torum. Last true molar, upper jaw, right side, half-worn, and presenting the distinctive characters of the species. The imperfect pit (*puits*) at the base of the posterior inner angle is developed exactly as in the specimens from the Val d'Arno, and as in a specimen from Malaga with which it was confronted. The enamel still is thin, and the outer surface is marked by very fine, parallel, closely appressed grooves. The tooth differs from the ordinary character chiefly in having the plate which is thrown off from the posterior barrel continued across the valley so as to form a bridge between the anterior and posterior barrels, isolating a portion of the transverse fissure into a round hole. This character is rare among the Rhinoceroses. (Dictated to the Rev. S. W. King by Dr. Falconer, 13th December, 1861.)

upper molar labelled by Dr. Falconer " the penultimate." It belonged to an animal in its full prime, and agrees exactly with the first upper true molar figured. In Mr. Fitch's collection also, in Norwich, there is a first upper true molar, together with one too much worn to have its position in the jaw accurately determined. In the British Museum there is an Etruscan left upper true molar 2, which was formerly in the Layton collection. The black ferruginous matrix which adheres to it proves that it was obtained from the Forest-bed, while its waterworn condition shows that it has been exposed to the waves of the sea. It was therefore most probably obtained from the Norfolk or Suffolk shore, or perhaps may have been dredged up from the bottom of the German ocean off that coast. It agrees in every respect with the true molar which I have described above. This list comprises all the Etruscan upper molars from British localities which have passed through my hands.

I will now pass on to the consideration of the teeth of *Rhinoceros Etruscus* from foreign localities. In a collection of Mammalia in the British Museum, obtained by M. Bravard from Perolles, are two teeth described in his catalogue as those of the Tichorine species; they belong, however, beyond all doubt, to the species under consideration. The one, a left upper true molar 3 (Pl. VIII. fig. 5), agrees in every respect with that of the jaw from Pakefield. The entrance, however, to the anterior valley is rather wider and and more open. The other is a left premolar 4 (Pl. VIII. fig. 2), very much worn, that probably belonged to the same animal as the last true molar. It presents all the characters ascribed above to the premolar series. To M. Lartêt I am indebted for evidence of the occurrence of the species in a second locality in France, afforded by a first premolar (Pm. 2), half worn, from the Pleiocene beds of Etampes (Pl. VIII. fig. 1). The entrances of the two valleys, a, b, are situated high above the cingulum. The guard, o, is very stout, and especially on the anterior aspect, and is removed from the cingulum by at least 0·3 inch. It sweeps round from the antero-external angle of the tooth as far as the apex of the postero-internal, and forms a pedestal from which the two colles, d and e, gradually taper upwards. The external lamina, l, is tumid, and the second costa, $k\,2$, is strongly marked. It presents one character not observable in any British specimen, in the insulation of an accessory valley by two combing-plates, h; as, however, they spring from the anterior wall of the second collis, e, they cannot be considered homologous with the anterior combing-plate, g, so characteristic of the Tichorhine species, in which the latter invariably springs from the external lamina. Both are therefore posterior combing-plates, h. A second specimen sent by M. Lartêt is a premolar 3, from Velay; it agrees with the description of the corresponding tooth from Norfolk in all points, except the great size of its posterior combing-plate, which is bounded by a waved line of enamel.

The remains of the species are more abundant in Italy than anywhere else; and there are several jaws and teeth from that country in the Museums of Oxford and London. In the British Museum

there is a fine upper true molar 1 (Pl. VIII. figs. 3 *a*, 3 *b*) from the Val d'Arno, which is but little worn, and therefore belonged to an adolescent animal; as compared with the English specimens it is remarkable only for its smaller size. The guard, *o*, is represented on its inner aspect by a line of cusps passing across the second collis, *e*, and blocking up the entrance of the anterior valley, *a*. In the same museum, also, there is a plaster cast of a skull containing five out of the six teeth. The first premolar presents the same feature as that described in the specimen from Etampes. The two posterior combing-plates have insulated a portion of the anterior valley, as in Pl. VIII. fig. 1; and there consequently appear on the worn crown-surface three islands of enamel*. In the Oxford Museum there is a fragment of the maxillary bone containing premolars 3, 4, and true molars 1, 2, brought from the Val d'Arno by Mr. Joseph Pentland. The teeth are very much shattered, with the exception of the first true molar. They present all the characters of the Etruscan species. This specimen is highly impregnated with iron, and has been derived from a sandy matrix. From the same deposit are preserved the teeth of *Elephas meridionalis*, *E. antiquus*, and *Hippopotamus major*; and its fluviatile or lacustrine origin is proved by the presence of a large species of *Anodon*†. Evidence also is afforded by an upper jaw of the animal found at Malaga, and now preserved in the British Museum, that the animal lived in the south of Spain. The teeth, which consist of the whole molar series, except premolar 4, agree exactly with those which have already been described‡.

4. *Permanent Lower Molar Dentition.*—The lower molar series (Pl. VII. fig. 3) of *Rhinoceros Etruscus* is easily distinguished from that of the Megarhine species, with which it is associated on the Cromer shore, by the possession of the following characters:—The teeth are much smaller and the unworn crowns are much lower. In the true molars also, the guard, *o*, before and behind is much more strongly marked. In true molars 1 and 2 it frequently crosses the base of the posterior area, *n*, and disappears in the median groove, *i*, and is always represented more or less by a line of tubercles. This character is strongly exaggerated in the premolars, in which there is a similar prolongation of the anterior guard backwards to meet the posterior in the middle of the median groove, *i*. The enamel structure throughout is also rougher than in the Megarhine teeth. As compared with the Leptorhine and Tichorhine species, it is differentiated by the presence of the guard, *o*, on the external lamina, by the lowness of the crown, the thickness of the enamel, and by the absence of costæ from the rounded anterior area, *m*. The finest specimen that has passed through my hands consists of the two rami that belong to the same animal as the upper molar series from Pakefield. They contain five out of the six molars, premolar 2 only being absent.

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* The remains of this species in the British Museum have now been largely increased by the accession of all the type specimens in the possession of the late Dr. Falconer.—January 1868.

† Described in Dr. Falconer's notes, Palæont. Mem. vol. ii. p. 354.

‡ Described by Dr. Falconer, vol. ii. p. 360.

The left ramus (Pl. VII. fig. 3) shows the typical molar dentition.
Many other lower jaws of the Etruscan species have also been obtained
from the Forest-bed ; one left ramus in the possession of Mr. Fitch,
of Norwich, was considered by Professor Owen[*] to belong to his Lep-
torhine species. Its correspondence, however, with other jaws which
are indisputably Etruscan, place its determination beyond all doubt,
although the only teeth it presents are the last milk-molar and the
germ of the true molar[†]. In the Norwich Museum there is a right
lower ramus, which belonged to an old adult, and a last true molar,
both of which were obtained by Miss Gurney from the Forest-bed.
In the Geological Museum at Cambridge there are also two rami
that contain four out of the six molars, and belonged to an animal
in the prime of life. They were found in the same locality as the
preceding, by Miss Gurney. A left lower ramus containing the true
molar series was forwarded to me by the Rev. John Gunn, which
had been named by Dr. Falconer *Rhinoceros leptorhinus* of Cuvier.
Its characters, however, read by the light of discoveries since his
death, show that it really belongs to *Rhinoceros Etruscus*. There
are also a few specimens in Britain of the lower molars of *Rhinoceros
Etruscus* from foreign localities, consisting of a lower jaw from the
Val d'Arno in Mr. Pentland's collection at Oxford, and some isolated
teeth from Perolles in the British Museum. None, without excep-
tion, that have passed through my hands, present any deviation
from the characters which have been ascribed above to the lower
molars of *Rhinoceros Etruscus*.

5. *Comparative Measurements.*—The measurements taken at the
base of the crown in inches and tenths are uniform with those of
the preceding essays on the Tichorhine, Megarhine, and Leptorhine
dentition. They are—

1. Antero-posterior, taken along the outside of the crown.
2. Antero-transverse, taken across the anterior lobe of the tooth.
3. Postero-transverse, taken across the posterior lobe of the tooth.

A comparison of the measurements of the Etruscan teeth with
those of the Pliocene and Miocene species will show the difference
of size existing between them.

TABLE OF MEASUREMENTS.

Upper Molar Series.

Species.	Locality.	Tooth.	1.	2.	3.
Rhinoceros Etruscus	Pakefield, Lowestoft............	Pm. 2	1·24	1·4	1·62
		Pm. 3	1·48	2·0	2·02
		Pm. 4	1·5	2·16	2·15
		M. 1	1·75	2·36	2·2
		M. 2	1·78	2·42	2·16
		M. 3	...	...	...
		M. 2	1·8	2·45	2·2
		M. 1	1·8	2·38	2·12
		Pm. 3	1·45	2·05	2·05
		Pm. 2	1·22	1·49	1·66

[*] Brit. Foss. Mammals, p. 381.   [†] See Falconer's note, § 2.

Species.	Locality.	Tooth.	1.	2.	3.
Rhinoceros Etruscus	Cromer (Rev. S. W. King)	Pm. 2	1·0	1·84	1·79
		Pm. 3	...	2·05	2·01
		M. 3	...	2·15	2·09
	Cromer (Rev. John Gunn)	M. 1	1·79	2·3	2·1
	Forest-bed (Brit. Mus., Layton Coll.)	M. 2	1·8	2·3	2·16
	Perolles (Brit. Mus., M. Bravard)	M. 3	1·89	1·93	...
		Pm. 3	1·38	2·0	1·75
	Etampes (M. Lartêt)	Pm. 2	1·21	1·45	1·59
	Velay (M.Lartêt)	Pm. 3	1·4	1·98	1·86
	Val d'Arno (cast, Brit. Mus.)	Pm. 2	1·35	1·55	1·68
		Pm. 3	1·55	2·03	2·03
		Pm. 4	1·6	2·25	2·1
		M. 1	1·62	2·20	...
		M. 2	1·88	2·38	2·25
		Pm. 2	1·23	1·5	1·53
		Pm. 3	1·35	2·05	1·95
		Pm. 4	1·4	2·25	1·95
		M. 1	1·6	2·2	2·09
		M. 2	1·73	2·3	2·2
	Val d'Arno (Oxford Mus.)	M. 1	1·75	2·23	2·1
	Malaga (cast, Brit. Mus.)	Pm. 2	1·26	1·5	1·6
		Pm. 3	1·55	1·9	1·85
		M. 1	1·6	2·1	2·0
		M. 2	1·95	2·35	2·1
		M. 3	2·2	2·2	...
Rhinoceros Schleiermacheri, *Kaup*	Miocene, Darmstadt	Pm. 1	1·0	0·45	1·65
		Pm. 2	1·25	1·44	1·7
		Pm. 3	1·45	2·9	2·0
		Pm. 4	1·49	2·19	2·06
		M. 1	1·9	1·7	2·4
		M. 2	1·98	2·6	2·39
		M. 3	2·2	2·28	...
Acerotherium incisivum, *Kaup*	Miocene, Darmstadt	Pm. 1	0·95	0·8	...
		Pm. 2	1·28	1·6	1·74
		Pm. 3	1·34	2·13	2·08
		Pm. 4	1·47	2·3	2·19
		M. 1	1·7	2·34	2·15
		M. 2	2·2	2·25	...
		M. 3	1·7	2·34	2·25
Rhinocéros d'Auvergne	Pseudo-pliocène d'Issoire	Pm. 1	0·92	0·48	0·88
		Pm. 2	1·2	1·55	1·6
		Pm. 3	1·35	1·95	1·9
		Pm. 4	1·48	2·2	2·05
		M. 1	1·58	2·15	2·1
		M. 2	1·88	2·25	2·1
		M. 3	2·48	2·15	...
Rhinoceros brachypus, *Lartêt*	Miocene, Ville-Franche d'Astarac	Pm. 1	...	...	...
		Pm. 2	1·28	1·55	1·7
		Pm. 3	1·4	1·95	1·98
		Pm. 4	1·62	2·23	2·1
		M. 1	2·12	2·7	2·3
		M. 2	2·1	2·6	2·25
		M. 3	2·75	2·6	...
Rhinoceros Simorrensis, *Lartêt*	Miocene, Ville-Franche d'Astarac	Pm. 1	0·6	0·6	...
		Pm. 2	0·9	1·12	1·34
		Pm. 3	1·05	1·6	1·6
		Pm. 4	1·13	1·68	1·68
		M. 1	1·38	1·75	1·58
		M. 2	1·48	1·7	1·6
		M. 3	1·6	1·55	...

Lower Molar Series.

Species.	Locality.	Tooth.	1.	2.	3.
Rhinoceros Etruscus	Pakefield	Pm. 3	1·38	1·0	1·08
		Pm. 4	1·42	1·13	1·22
		M. 1	1·45	1·2	1·23
		M. 2	1·75	1·26	1·24
		M. 3	1·75	1·15	1·18
		M. 3	1·72	1·15	1·19
		M. 2	1·72	1·25	1·22
		M. 1	1·59	1·19	1·2
		Pm. 4	1·45	1·12	1·22
		Pm. 3	1·35	1·0	1·1
	Forest-bed (Cambridge Mus.)	Pm. 4	1·45	1·0	·95
		M. 1	1·5	1·12	1·12
		M. 2	1·75	1·2	1·15
		M. 3	2·2	1·2	1·15
	Cromer (Rev. John Gunn) ...	M. 1	1·85	1·2	1·14
		M. 2	1·77	1·19	1·14
		M. 3	1·85	...	1·05
Rhinoceros Schleier-macheri, *Kaup* ...	Miocene, Darmstadt	Pm. 1	...	...	...
		Pm. 2	1·19	0·72	0·89
		Pm. 3	1·55	1·02	1·08
		Pm. 4	1·08	1·18	1·25
		M. 1	1·85	1·25	1·45
		M. 2	1·99	1·45	1·52
		M. 3	1·85	1·38	1·25
Acerotherium incisi-vum, *Kaup*	Miocene, Darmstadt	Pm. 1	0·6	1·55	...
		Pm. 2	1·2	0·88	0·9
		Pm. 3	1·4	0·95	1·5
		Pm. 4	1·45	1·1	1·1
		M. 1	1·65	1·11	1·15
		M. 2	1·75	1·25	1·25
		M. 3	1·6	1·1	1·09
Rhinoceros Simor-rensis, *Lartêt*	Miocene	Pm. 2	1·05	0·53	0·72
		Pm. 3	1·2	0·78	0·88
		Pm. 4	1·34	0·9	0·95
		M. 1	1·42	1·95	0·98
		M. 2	1·45	0·98	1·0
		M. 3	1·48	0·9	0·92

6. *Affinities.*—The Megarhine and Leptorhine Rhinoceros present, as we have seen in the preceding essays*, dental characteristics which are now shared among the living and widely divergent species ; the Etruscan, on the other hand, points rather backwards than forwards in time, and its dental characters are represented only by the milk-teeth of some of the Rhinoceroses that lived after its extinction. The teeth of the genus *Rhinoceros* may be divided into two distinct classes, characterized severally by the height or lowness of their unworn crowns, and especially in the case of the upper molar series. To the high-crowned or hypsodont† division belong all the living and all the Pliocene and Pleistocene species, with the exception of *Rhinoceros Etruscus* and perhaps *R. pachygnathus* of Pikermi.   To it also belong all the Rhinoceroses from the Sivalik Hills.   The typical

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* Nat. Hist. Rev. 1865, No. XIX.   Quart. Journ. Geol. Soc. vol. xxiii. p. 227.
† ὕψος = height, ὀδούς = tooth.

hypsodont dentition reaches a maximum of development in the *R. tichorhinus, R. platyrhinus,* and *R. simus.* To the second or bra-chydont* division belong *Rhinoceros Etruscus* and all the Miocene species both of Europe and North America, the only exception being presented by those from the deposit in the Sivalik hills, which seems to me by no means of indisputable Miocene age. Into this group also falls the remarkable hornless Rhinoceros, the *Acerothe-rium incisivum.* This form of tooth, so universal in Miocene times, is preserved now only in the deciduous teeth of the recent and fossil species. We have therefore to compare *Rhinoceros Etruscus* with Miocene rather than Pliocene or Pleistocene members of the genus; and so closely does it approach some of these that an isolated tooth could hardly be determined with absolute certainty if the locality were unknown. All its characteristics occur in an intensified form, but are not altered in any essential point. It differs from the Rhi-noceros of Auvergne only by the greater complexity of the anterior valley, by the larger development of the posterior combing-plate, and by the more slightly defined guard on the inner aspect of the pre-molar series. In the latter species, however, the first premolar, pm. 1, is persistent, so that it presented the normal molar formula of the placental mammals. The exact geological horizon of this species is very obscure. It was derived, according to M. Gervais †, from the " pseudo-pliocène d'Issoire," and is the same as the *R. elatus* of the Abbé Croizet, and has even been referred to the *R. me-garhinus* of M. de Christol. The *Rhinoceros brachypus,* Lartêt, from the Miocene of Ville-Franche d'Astarac, in Auvergne, has also four persistent premolars. It diverges from the Etruscan species in the following points :—The guard on the inner surface of the true molars, which is merely sketched out in *R. Etruscus,* is fully and strongly developed ; the strongly impressed guard in the premolars on the posterior area, and in the true molars on both areas ; the posterior combing-plate is not so strongly marked. The crowns of the premolars are worn flat, while those of the true molars are ex-cavated ; but this may possibly be a mere peculiarity of the indi-vidual. In the lower molars of the same animal the guard is far more strongly impressed on both areas, and especially so in the pre-molars, and is very pronounced on the inner aspect of the anterior collis, which it traverses diagonally. The dentition of *R. Simor-rensis,* Lartêt, from the same locality as the last, presents the fol-lowing points of difference :—In the upper jaw the guard is more strongly impressed on the true molars, more slightly on the pre-molars. The lower jaws, however, of the two animals are identical in form. Premolar 1 is present in both, being very small rela-tively to the other teeth, and a mere representative of a departing structure. All the teeth are very much smaller. The *Rhinoceros Etruscus* is more or less allied to all these in the form of its teeth ; but its closest ally is the hornless Rhinoceros of Darmstadt, the *Acerotherium incisivum* of Kaup (= *R. incisivus,* Cuvier). The latter, however, is defined by the large incisors and by the persistence of

* βραχὺs = short, οδοὺs = tooth.   † Paléontologie, p. 59.

premolar 1. The guard round the inner bases of the premolars is somewhat stouter, but at the base of the posterior area is less developed. The posterior combing-plate in the last upper true molar does *not* insulate the head of the valley. In the lower molar series there is not the slightest trace of a guard. With these exceptions the teeth of the two species resemble one another so closely that it would be impossible to determine the separate molars of the one from those of the other. These points of difference are also found in *R. Schleiermacheri*, from the same locality; but in addition the teeth of the latter animal are rather higher, and the *third costa* is more strongly marked on the posterior area of the premolar series.

The second upper true molar of the Etruscan species bears a remarkable resemblance to the last upper milk-molar of the Megarhine; so close, indeed, is this that for a long time I classified an isolated tooth in the British Museum with those of the latter species, the only difference observable between them being the slightly thicker enamel, and the slightly more massive form of the Etruscan tooth. The same mistake, however, could not happen in the case of the milk-teeth of any other recent or fossil species; for the differences are so strongly marked that they need no mention in this place. Thus the permanent molar series of *R. Etruscus* is closely related to several of the Miocene species, and especially to that of *Acerotherium incisivum* and *R. Schleiermacheri*, the only exception being that one of the teeth is represented in the milk-dentition of *Rhinoceros megarhinus*; we are therefore compelled to admit the Miocene character of *R. Etruscus*. Of the three other Pleistocene species, *Rhinoceros tichorhinus*, the most modern of them, stands in close relationship with the *R. simus* of India, while *R. megarhinus* and *R. leptorhinus* of Owen are closely related to the bicorn Rhinoceros of Sumatra. The Etruscan species, on the other hand, stands aloof from all these, and is to be viewed as the last representative of a Miocene type that lingered on into the first stage of the Pleistocene period, its peculiar adult dentition being found in none other of the Pleistocene species; and with it the hypsodont form of tooth universal in the Miocene of Europe became obsolete.

7. *Range in Space and Time.*—I have now, in conclusion, briefly to review the range of the species in space and time. It has not yet been proved to have existed in Germany*, nor has it been found elsewhere in any deposit of clearly Postglacial age. It wandered over the Italian portion of the Pliocene continent along with *Elephas meridionalis*, *E. antiquus*, *Hippopotamus major*, and *Rhinoceros megarhinus*. Thence it passed northwards, together with the great bulk of the Italian Pliocene fauna, into France, and westward into Spain, and advanced as far north as the low-lying country that now forms the bed of the German ocean, where it occurs in the Preglacial forest of the Norfolk and Suffolk shore. Its abundance

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* The animal from Faxland, near Carlsruhe, described and figured by Hermann von Meyer under the name of *R. Merki*, is considered by M. Lartêt to belong to the Etruscan species. If this determination be true, the range of the animal must be extended to the valley of the Rhine.

ETRUSCUS.

UPPER PREMOLARS AND MOLARS OF RHINOCEROS ETRUSCUS.

De Wilde lith.
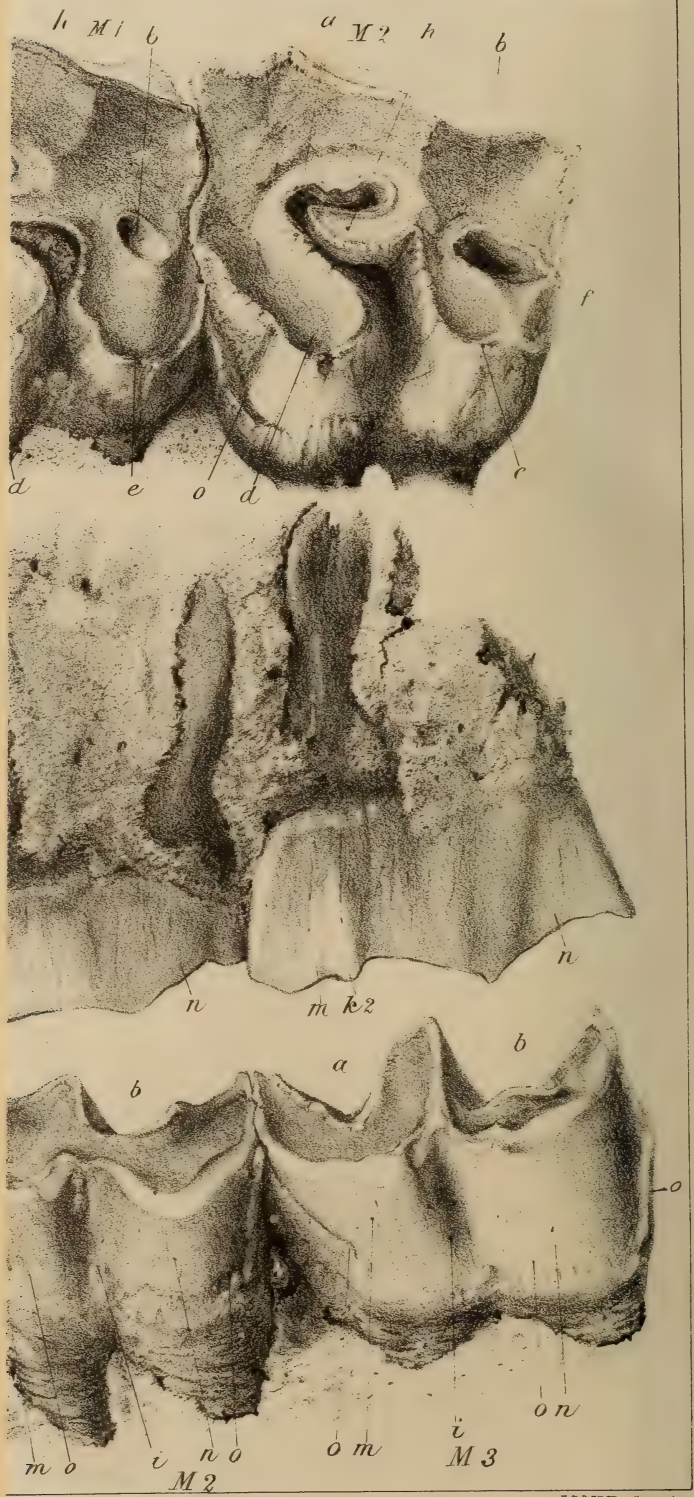
M & N Hanhart imp.
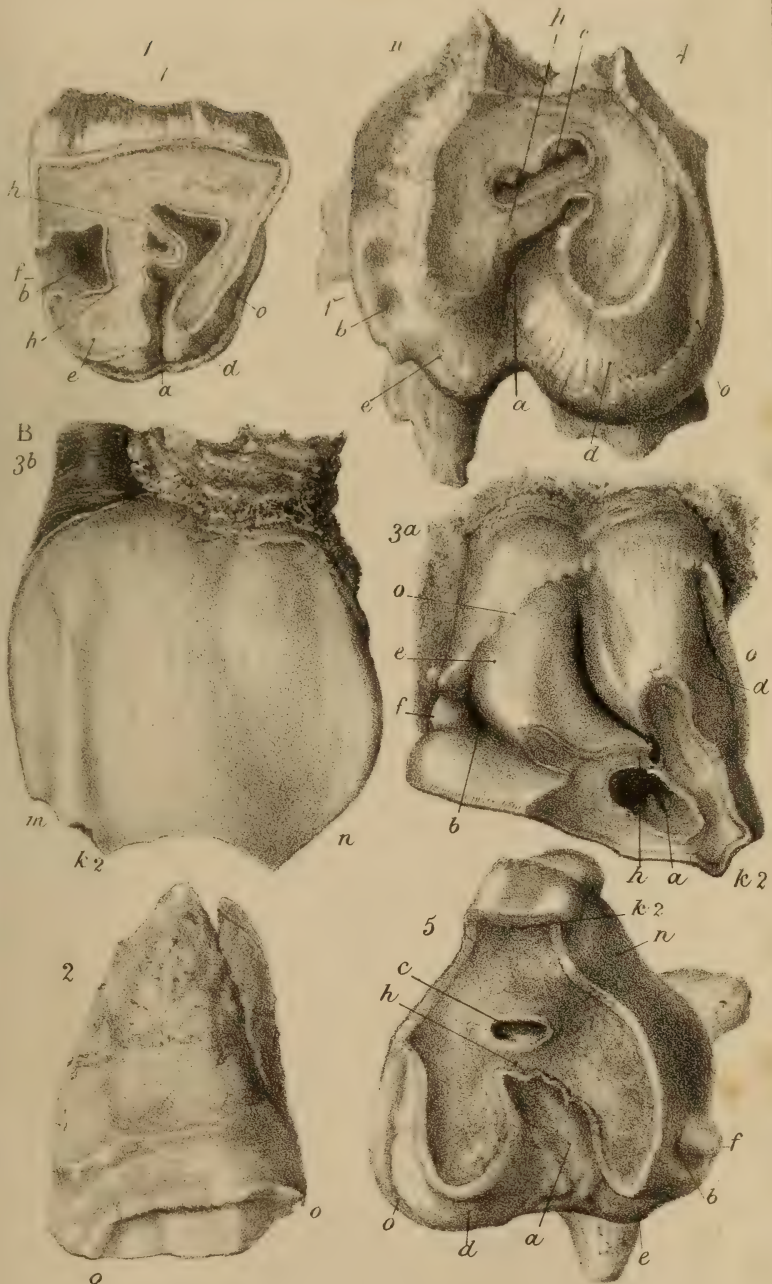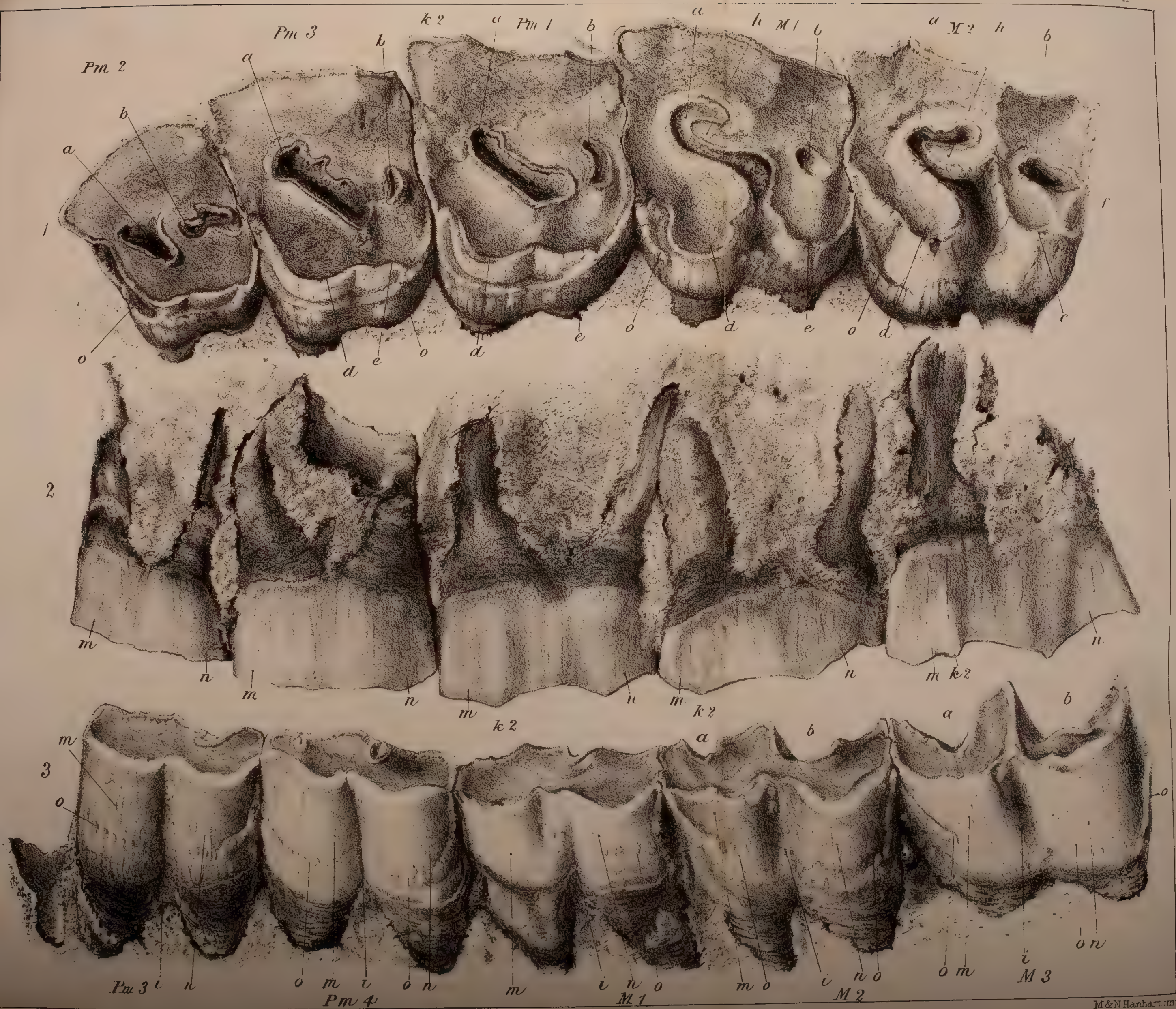
LEFT MOLAR SERIES OF RHINOCEROS ETRUSCUS.

UPPER PREMOLARS AND MOLARS OF RHINOCEROS ETRUSCUS.
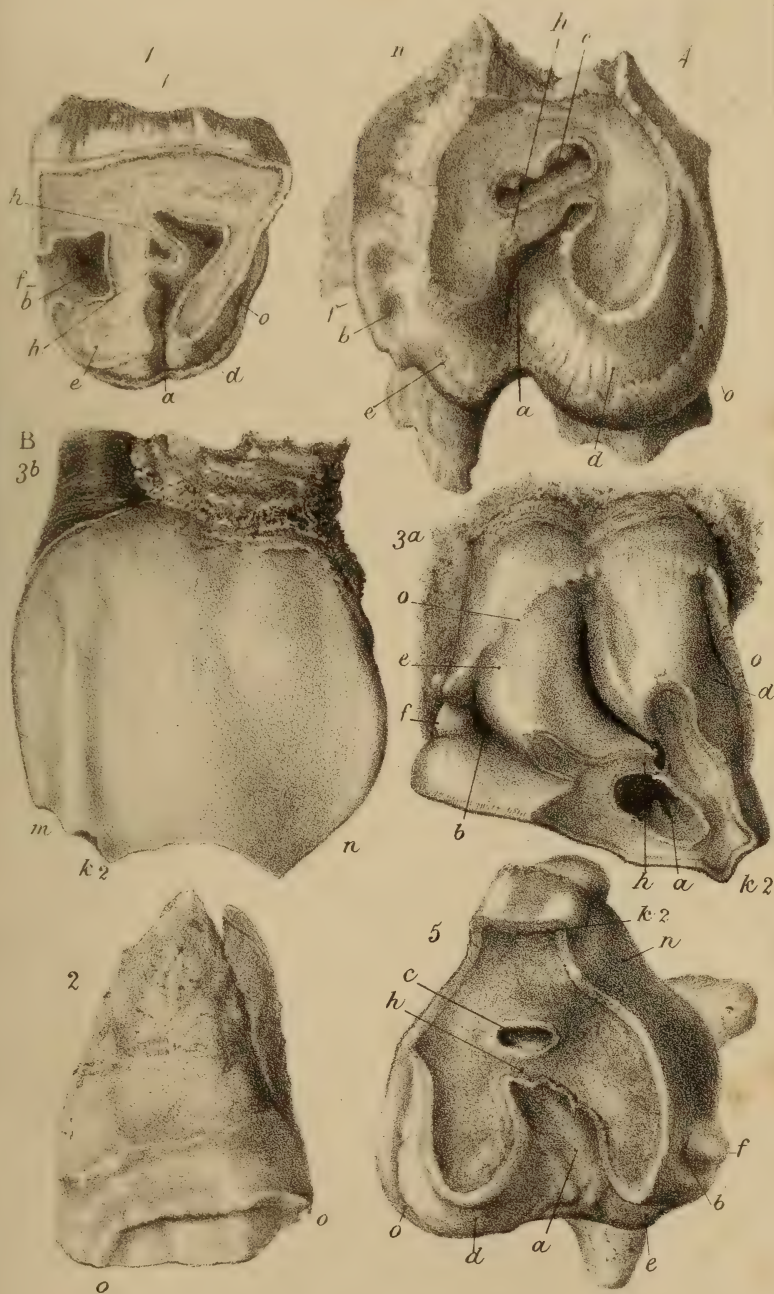
in Italy proves that its headquarters were in that country. No-
where is it associated with any of the animals fitted for living in a
severe climate. As the temperature of Preglacial France and
Britain became lowered at the approach of the Glacial epoch, it
retreated southwards, and most probably made its last stand in
Spain and Italy. There is not the slightest trace of its ever having
coexisted with *Rhinoceros tichorhinus*, which was its representative
in the Postglacial European fauna that, favoured by the cold, passed
southward over the Alps, at least as far as Rome. There has always
been considerable doubt as to the exact correlation of the Italian
Pliocenes with the Postglacial deposits of France and Britain, be-
cause of the great probability that while animals capable of living
in a northern climate dwelt in those countries, a southern fauna
inhabited Italy. This point has lately been settled by the dis-
coveries of M. Caselli*, who has proved that the Cave-Hyæna and
Cave-Bear, the Mammoth, and Glutton passed southwards and
established themselves, to say the least, in the midst of the Italian
Pliocene fauna. We have therefore the means of knowing that
the great ossiferous deposits of the Val d'Arno are of Preglacial
age, because they contain animals exclusively of a southern type.
Even in Italy we have no proof that the Etruscan Rhinoceros was
living at the time of the irruption of the Postglacial mammals.

    In the following table I have represented the range in time of the
four fossil Rhinoceroses found in British Pleistocene deposits, that
their value in classification may be seen at a glance.

	Rhinoceros tichorhinus.	Rhinoceros megarhinus.	Rhinoceros leptorhinus, *Owen.*	Rhinoceros Etruscus.
Postglacial	*	...	*	...
Glacial	...	...	...	...
Brickearths of Thames Valley......	*	*	*	...
Preglacial	...	*	...	*
Pliocene	...	*	*	*

EXPLANATION OF PLATES VII. & VIII.
(All the Figures are of the natural size).

PLATE VII.

Fig. 1. Crowns of left upper Molar series, except m. 3.   Pakefield.   Nat. size.
    2. External laminæ of the same specimen, natural size.
    3. External laminæ of left lower Molar series, except pm. 2.   Pakefield.

PLATE VIII.

Fig. 1. Right upper Premolar 2.   Etampes.   M. Lartêt.
    2. Inner view of left upper Premolar 3.   Pérolles.   Brit. Mus.
    3 *a.* Inner view of left upper true Molar 1.   Val d'Arno.   Brit. Mus.
    3 *b.* External lamina of the same.   *Ibidem.*
    4. Crown of right upper Molar 3.   Pakefield.
    5. Crown of left upper Molar 3.   Pérolles.   Brit. Mus.

        * Correspondance de Rome, May 5, 1867.

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POSTSCRIPT.—The 'Palæontological Memoirs' of Dr. Falconer, published a few days after the reading of this Essay before the Society (Jan. 8, 1868), contain notes on *Rhinoceros Etruscus*, and many beautiful plates of jaws and teeth for the most part from Italy (vol. ii. p. 354–368, pls. 25–29). With the sole exception of the terminology being different, Dr. Falconer's definition of the species is identical with my own. In the same work also there are Essays on the three other species of Rhinoceros found in Great Britain, which (if the name *R. antiquitatis*, Blum., be substituted for *R. tichorhinus*, Cuvier, *R. hemitœchus*, Falc., for *R. leptorhinus*, Owen, and *R. leptorhinus*, Cuvier, for *R. megarhinus*, De Christol) differ but very slightly from those which form the series of which the memoir on *R. Etruscus* is the conclusion. The difference is merely one of names; and the conclusions arrived at independently of each other are identical.—W. B. D., Feb. 29, 1868.

JANUARY 22, 1868.

James Trubshaw Johnson, Esq., Mining and Civil Engineer, Lichfield, Staffordshire, and Stephen Brown Dixon, Jun., Esq., Pewsey, Wilts, were elected Fellows.

The following communications were read:—

1. *On the* SPEETON CLAY. By JOHN W. JUDD, Esq., F.G.S., of the Geological Survey of England and Wales.

CONTENTS.

I. INTRODUCTION.

IN the attempt to study the Neocomian formation as developed in this country, my attention has been directed for some years past to the series of beds in Yorkshire which since 1829 has been known as "the Speeton Clay." I have found that, although a very great variety of opinions had been expressed concerning the age of this formation, but little had been done towards working out in detail the true

succession of the beds which compose it ; and, as this part of the Yorkshire coast-section is greatly complicated by faults and contortions, and much obscured by landslips and drift, I soon became convinced that it was only by such detailed and systematic examination that satisfactory conclusions were to be arrived at.   The fact that the mining operations now pursued on an extensive scale at these cliffs are rendering this *unique* section every year more and more obscure acted as a further incentive ; and I accordingly determined on the execution of the following tasks :—

1. A careful survey of the Speeton Cliffs, and the construction of a map and section upon a very large scale, showing the various landslips &c., with a view to arriving at the true succession of the beds. The necessary basis for this work was opportunely furnished by the publication in 1862 of the beautiful 6-inch Ordnance Map of this part of the Yorkshire coast.

2. The collection of the fossils and drawing up accurate lists of the contents of the several beds.   The incompleteness of the various collections of Speeton fossils, the absence of notes on the specimens in those collections, indicating from what portion of the section they were obtained, and the large admixture of species not belonging to the deposit at all rendered this task indispensable.

3. The critical examination of the undoubted Speeton fossils, and a comparison of them with the figures and descriptions contained in the works of continental palæontologists, and, where possible, with authentic foreign specimens.   The possession by the British Museum of an extensive series of foreign Neocomian fossils, from the collection of MM. Astier, Paul Mohr, and others, greatly facilitated this part of my undertaking.

II. Bibliography of the Subject.

The earliest notice of the Speeton Clay with which I am acquainted is that of Young and Bird[*], who in 1822 gave a very careful and exact account of the physical character of these beds, with figures and descriptions of a few of the fossils.   They called these strata " the Upper Shale," but made no serious attempt at their correlation.

In 1826[†] Professor Sedgwick gave a detailed description of the Speeton section (from observations made in 1821), and referred the clays to the Kimmeridge, noticing, however, the peculiarity in the fauna of their upper portion.

In Phillips's ʻGeology of Yorkshire'[‡] the beds are described under the name of the Speeton Clay, a considerable number of the fossils are figured, and the striking distinction between those from the upper and lower part respectively clearly pointed out ; the former were assigned to the Gault, the latter to the Kimmeridge Clay.

[*] Survey of Yorkshire Coast, 1st ed. (1822), 2nd ed. (1828).
[†] " On the classification of the strata which appear on the Yorkshire Coast," Ann. of Philosophy, vol. xi. (1826) p. 339.
[‡] 1st ed. (1829) p. 76.

At a meeting of the Geological Society of France, April 16, 1838[*], M. Agassiz, whose long and very intimate acquaintance with the typical Neocomian fauna makes his testimony particularly valuable, stated that an examination of the Speeton fossils in the York Museum had convinced him that the beds were of Neocomian age.

In 1840[†] M. Römer, in describing the Hilsthon and Hilsconglomerat of North-western Germany, pointed out very clearly their parallelism with the Speeton Clay on the one hand, and the Swiss Neocomian limestone on the other.

In 1843[‡] Mr. Godwin-Austen gave expression to a very strong opinion in favour of the Neocomian age of the Speeton Clay.

Professor Edward Forbes, who had the opportunity of examining a large collection of Speeton fossils in the possession of the late Marchioness of Hastings, appears to have arrived at the same conclusion[§].

Almost at the same time Dr. Fitton published his views of the Speeton Clay, which entirely coincided with those of Mr. Godwin-Austen and Professor Forbes[||].

M. Alcide D'Orbigny[¶], in his various works, placed the Speeton fossils, somewhat arbitrarily, with those of the Lower Greensand in his *Etage Aptien* (Upper Neocomian). He was, however, compelled to admit some of the species to be those of the Lower Neocomian.

In 1851[**] M. d'Archiac, after carefully balancing the various evidence on the subject, assigned the upper part of the Speeton Clay to the Neocomian formation.

Mr. John Leckenby in 1859[††] gave a description of the Speeton Clay, in which we find the earliest attempt at a classification of the beds which compose it, with a discrimination of the fossils belonging to each. A short notice of the strata of Filey Bay, contributed by the same author to a local guide-book[‡‡], contains the most complete list of Speeton fossils hitherto published. Lastly, in a note supplied to and published by Dr. Wright[§§], Mr. Leckenby pointed out two most important facts, namely, the existence of a band of phosphatic nodules at the junction of the Cretaceous and Jurassic portions of the Speeton Clay, and the existence in the latter of a Portlandian fauna. In his various papers Mr. Leckenby has added the weight of his valuable opinion in favour of the Neocomian age of the upper portion of the Speeton Clay.

III. General Description of the Coast-section at Speeton.

Immediately to the north of the bold range of chalk cliffs forming Flamborough Head, and separated from it by a deep ravine called

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[*] Bull. Soc. Géol. Fr. 1re Sér. tome ix. p. 262 (1838).

[†] Verst. nordd. Kreid. See also Letter to Dr. Fitton in Proc. Geol. Soc. vol. iii. p. 323.

[‡] Proc. Geol. Soc. vol. iv. p. 196.

[§] Quart. Journ. Geol. Soc. vol. i. (1845) p. 78.

[||] Ibid. p. 186, note.

[¶] Cours élémentaire, &c. tome ii. 2. p. 608 ; Prodrome, pp. 112–121.

[**] Hist. des Prog. de la Géol. vol. iv. p. 61.

[††] Geologist, 1859, p. 9.   [‡‡] Cortis's Guide to Filey.

[§§] Mon. of Brit. Fos. Cret. Echin. (Pal. Soc.) p. 9 (1864).

" Speeton Gap," we find a lower range of cliffs of clay much tumbled and broken, and sending out long promontories or spurs, which reach the high-water mark. This clay cliff-range extends in length about 1000 yards, and varies in height from 150 to 220 feet. It is divided by projecting spurs into three well-marked portions, which are known by the names[*] of Black Cliff, Middle Cliff, and New Closes Cliff. The southern portion of the range is almost free from drift; but in going northwards beds of Boulder-clay and contorted drift are found to descend and occupy more and more of its face, until, at the northern extremity of the New Closes Cliff, they reach the level of the sea. North of this point the cliffs of Filey Bay are almost entirely composed of drift; and it is only at a few spots that, by the aid of landslips in the cliffs, by scars exposed at low-water, or by the occasional scouring of the beach during heavy storms, the subjacent rocks are exposed. At Filey Brigg the lowest beds of the Coral Rag and those of the Lower Calcareous Grit rise above the level of the sea, and are seen beneath the Boulder-clay.

The beds of the Speeton Clay are quite unconformable with those of the Chalk and Hunstanton limestone which lie upon them. While the latter strata have but a very slight dip (amounting, according to Young and Bird[†], only to about 100 feet per mile, or even less), the clays, as seen in the cliff, have an apparent dip of about 7°; the true dip, however, does not coincide with that of the section, its real direction being S.W., and its amount 10°. The strata at this part of the Yorkshire coast exhibit signs of great disturbance: while in some places they lie very evenly, in others they are thrown into great undulations. Professor Sedgwick[‡], in 1826, called attention to the fact that the beds of chalk as seen in the cliff between Speeton Gap and Flamborough Head are violently contorted; and a similar phenomenon is exhibited in the Hunmanby cutting of the Hull and Scarborough Railway. The clay beds of the New Closes Cliff are likewise contorted; at the time of the publication of ' The Geology of Yorkshire ' these contortions were manifest to a spectator looking at the cliff; and Professor Phillips has given a diagram[§] of them drawn to scale, which diagram is rendered of greater value by the fact that the mining operations for procuring phosphatic nodules have now entirely concealed the face of this part of the cliff. Any one, however, who will take the trouble to go through the workings may easily satisfy himself concerning the highly disturbed positions of the beds in this place. I shall show in the sequel that these undulations of the strata extend for at least a mile north of this spot. Lastly, the beds of Coralline Oolite which form Filey Brigg exhibit similar, though less violent, contortions.

Professor Sedgwick describes[||] a *fault* as occurring at the junction

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[*] To obviate the difficulty arising from the usual confusion in local nomenclature, I have throughout the present paper used the names printed on the six-inch Ordnance map of this district.

[†] Survey of Yorkshire Coast, p. 51 (2nd ed., 1828).

[‡] Annals of Philosophy, vol. xi. (1826) p. 342.

[§] Geology of Yorkshire, pl. 8.　　　　[||] Ann. of Phil. vol. xi. (1826) p. 343.

of the chalk and clay, while no such fault is represented in Professor Phillips's section of this part of the coast*. I regret that, owing to the great landslips at this spot, I found it impossible to arrive at a result which I could consider absolutely conclusive on this subject; I am, however, very strongly of the opinion, arrived at from an examination of the beds along the sides of Speeton Gap, that such a fault does exist, and that it is a downthrow towards the south, by which the Chalk beds are brought to a relatively lower level than those of the Speeton Clay. The direction of this fault appears to coincide almost exactly with that of the Speeton Gap, and it probably extends for some distance inland : its amount would appear to be very considerable; but I am unable to give even an approximate estimate of it.

The difficulty of reading the Speeton section is increased by the numerous landslips which occur along its course ; of these it is necessary to take account before attempting to arrive at the true succession of beds. Besides a great number of smaller masses of the drift and higher portions of the clay which have descended from their proper position and now occupy various levels down to that of high-water mark, there are three landslips which have produced very great and striking alterations in the features of the section. South of Speeton Gap the junction of the chalk and clay is altogether concealed, owing to the fact that great masses of the former have slipped over the latter, and now form an undercliff which extends for more than half a mile in length, and rises to a height of upwards of 100 feet. In Black Cliff another landslip has occurred, by which a mass consisting of the highest beds of Speeton Clay, capped by red and white chalk rubble, has descended 150 feet below its true level, and now occupies the base of the cliff for a length of 150 yards. Lastly, a similar, though smaller, slip has taken place in the southern part of New Closes Cliff, by which the highest beds at that part of the cliff are brought down to within 50 feet of the sea-level.

The thickness of the mass of clays composing the cliff I have been describing is about 500 feet, that of the beds below, which are so very partially exposed, cannot be estimated; but, considering the breadth of their outcrop, it must be very great. I shall now proceed to show that this great mass of clays is by no means uniform, either in lithological or palæontological characters, but that, on the contrary, it exhibits a number of well-marked subdivisions. At least seven such divisions, each distinguished by a clearly defined fauna, occur in this thick series of clays, some of which can be correlated with other British deposits already well known, while others are of higher interest as presenting us with representatives of formations not hitherto recognized in this country. The three upper of these divisions belong to the Neocomian System, the four lower to the Jurassic.

Thus it will appear that the Speeton Clay, far from being a single insignificant bed, is a formation at least equal in *thickness*, and, I

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* Geology of Yorkshire, pl. 3.

believe, taking into consideration the number of faunas which it represents, in *importance* also, to the English Lias.

IV. Is the Speeton Clay the Equivalent of the Gault?

Before entering upon the detailed description of the various strata composing the Speeton Clay, which is the principal object of this paper, I propose to reexamine the evidence on which some of them been referred to the age of the Gault.

The recognition of the important fact that the fauna of the upper part of this formation had Cretaceous rather than Oolitic affinities is due to Professor John Phillips, and is a great step in advance of any previous attempt at the correlation of these beds. When we consider the crude condition of the sciences of Geology and Palæontology at the date of the publication of 'The Geology of Yorkshire,' we shall be struck in this, as in so many other instances in the same remarkable work, with the success of its bold generalizations; and, remembering that the very existence of the typical Neocomian fauna was not pointed out by MM. Montmollin[*] and Thurmann[†] until six years later, we shall be satisfied that any nearer approximation to the determination of the real age of the Speeton Clay was at that time impossible. Unfortunately the reference of this formation to the Gault, which was at the first little more than a suggestion on the part of the author, and which has ever since been regarded by him as doubtful, has been too frequently treated by others as if conclusively established.

Besides the direct palæontological evidence on this subject, there is an *a priori* argument, deducible from the stratigraphical relations of the beds, which I think is entitled to considerable weight. The Hunstanton limestone (Red Chalk) has now yielded an abundant and well-marked series of fossils, which enables us to refer it to its true position in the geological scale. Now I am but expressing the conviction of all palæontologists who have examined the subject of late years when I say that this bed cannot be of *later* age than the Upper Greensand, and may be of as *early* age as the Gault. But between this bed and the Speeton Clay we have, as Professor Phillips himself has so well shown[‡], an enormous unconformity, certainly one of the greatest and most striking which occurs in this country. On the supposition that the Speeton Clay or any part of it is of the age of the Gault, we are driven to the conclusion that this remarkable unconformity exists either between the Upper Greensand and the Gault, or in the midst of the Gault itself —a conclusion, I need hardly say, not only altogether at variance with what we know of the stratigraphical relations of these beds, both in this and other countries, but also directly opposed to what we might expect from a comparison of their faunas; for, as has

* "Mémoire sur le terrain crétacé du Jura," Mém. de la Soc. des Sc. Nat. de Neuchâtel, vol. i. p. 49 (1836).
† Bull. de la Soc. Géol. de France, vol. ix. p. 46 (1837).
‡ *Vide* Map of Yorkshire; also 'Geology of Yorkshire' and Quart. Journ. Geol. Soc. vol. xiv. p. 84 (section).

been so amply shown by Professor Ramsay*, a great unconformity between two series of beds is always accompanied by a striking discrepancy between their fossil contents.   Such a discrepancy, however, is not found between the faunas of the Upper Greensand and Gault, but is well known to exist between those of the last-mentioned formation and the Neocomian.

Now let us turn to the direct palæontological evidence for referring the Speeton Clay to the age of the Gault.   Professor Phillips gives the following list of fossils† as common to the two formations :—

Ammonites planus ? *Mant.*
Hamites intermedius ? *Sow.*
—— rotundus, *Sow.*
—— attenuatus, *Mant.*
—— alternatus, *Mant.*
—— plicatilis, *Mant.*
Belemnites minimus, *List.*

Rostellaria composita, *Sow.*
Nucula ovata, *Mant.*
Pholadomya decussata, *Mant.*
Vermicularia Sowerbyi, *Mant.*
Spatangus argillaceus, *Phill.*
Caryophyllia cornulus, *Phill.*

The specimens referred to *Am. planus,* Mant. (which is only one of the numerous varieties of *A. splendens*), have now been long recognized as certainly not referable to the Gault species, but as belonging to a well-known Neocomian form, the *Ammonites Nisus* of D'Orbigny.   (*Vide* Morris's Catalogue and D'Orbigny's Prodrome.)

The various species figured by Young and Bird, Phillips and Römer, as *Hamites* (generally from very small fragments only) I shall show in the sequel to be really referable to the genus *Ancyloceras,* and usually to well-known Neocomian species and varieties of that genus. (*Vide* Appendix B.)

Belemnites minimus, I believe, really occurs in the Speeton Clay, but rarely, while in the Gault and Hunstanton limestone its prodigious abundance is most striking.

Rostellaria composita is probably a misprint for *R. Parkinsoni,* under which name, as Professor Forbes has shown, a number of species, both Gault and Neocomian, have been confounded‡.

Nucula ovata.—Professor Phillips's type specimens of this species are both young shells.   I have had the opportunity of examining a number of specimens of all ages, and believe that they are referable to *N. planata,* Desh., which is probably only a variety of *N. obtusa,* Sow.

Pholadomya decussata. — The type specimen is so crushed and distorted that it is impossible to form any certain judgment as to its affinities.   There is but little resemblance between it and Mantell's species from the Chalk-marl; and I believe it to be the *Pholadomya Martini,* Forbes, a shell which is certainly not uncommon in the Speeton Clay.

Vermicularia Sowerbyi.—It is difficult to form a judgment on the agreement of the species so abundant in the Speeton Clay with that figured by Mantell from the Chalk-marl, on account of the imperfect character of the drawing in 'The Geology of Sussex.'

* Anniversary Addresses to the Geological Society, 1863, 1864.
† Geology of Yorkshire, 2nd ed. (1835) p. 350.
‡ Quart. Journ. Geol. Soc. vol. i. (1845) p. 350.

Not the slightest doubt, however, can exist as to its identity with the species occurring in the Hilsthon, and figured by Römer under the name of *Serpula Phillipsii.* (*Vide* Röm. Verst. nordd. Kreide. p. 102, t. 16. f. 1. Mor. Cat. 2nd ed. p. 94.)

Spatangus argillaceus, Phill., is, on the authority of Agassiz himself, only a synonym of *Toxaster complanatus,* Ag., which is probably the most abundant and characteristic of all the Lower Neocomian fossils. (*Vide* Appendix B.)

Caryophyllia conulus, Phil.—I have long doubted the identity of the minute Yorkshire coral with the large and well-marked species from the Gault, figured and described by Milne-Edwards and Haime. Mr. Dallas, who kindly made a comparison for me, found it impossible to come to any certain conclusion on the subject, owing to the imperfect state of preservation of the type specimens.

On the other hand, I shall show that in the highest division of the Speeton Clay a great number of species occur which are eminently characteristic of the Lower Greensand and Atherfield Clay, as *Perna Mulletii,* Desh., *Ammonites Deshayesii,* Leym., *Belemnites semicanaliculatus* (Blain. ?), *Nautilus plicatus,* Sow., and *N. radiatus,* Sow., *Exogyra sinuata,* Sow., *Thetis Sowerbii,* Röm., *Panopœa plicata,* Sow., *Panopœa Neocomiensis,* Desh., *Terebratula sella,* Sow., and many others.

It may perhaps be argued that possibly a representative of the Gault may really exist at the top of the Speeton Clay, though hidden by the unconformable overlap of the Hunstanton limestone; but, for reasons already given, I consider this highly improbable, and believe the Gault, if not represented by the Red Chalk, to be altogether absent from the Yorkshire coast.

V. Classification of the Beds constituting the Speeton Clay.

A. *Upper Neocomian.*—Of course, owing to the overlap of the Cretaceous beds, the section of the Speeton Clay is incomplete in its upper part; and further, as I have already stated, the true junction of the Hunstanton limestone with the clays is always concealed by landslips.

The highest bed of the series which is visible at Speeton consists of black clays containing small and beautifully crystallized nodules of pyrites, which appear to be always aggregated in nests or irregular layers. This bed is nearly destitute of organic remains, the only fossils which I have been able to detect in it up to the present time being small Belemnites, which are always in a fragmentary condition. This black clay is seen at several points along the base of the undercliff of white chalk, as well as in Speeton Gap; it also makes its appearance in the upper part of Black Cliff, where it is covered by a bed of red chalk rubble (which is probably not far from its original position); and, lastly, it is seen in the landslip at the base of the same cliff.

Below these almost unfossiliferous black clays we find others of a dark-blue colour, in which fossils occur, but are by no means nu-

meros, and are of but few species.   These clays are about 50 feet
thick, and contain a few scattered septaria, of small size, composed
of argillaceous ironstone of a pale-brown colour, and having extremely
thin septa composed of crystallized pyrites.   The small number of
species of fossils occurring in this bed are all common to it and the
bed below.   They are as follows :—

C.* Belemnites semicanaliculatus (*Blain.* ?).	c. Vermicularia Phillipsii, *Röm.* sp.
c. Belemnites minimus, *List.*	r. Alaria (?), sp.
	r. Rhynchonella sulcata, *Park.*

The base of the highest division of the Speeton Clay is formed
by the well-marked band known to the workmen as the " Cement-
bed."   It consists of a very light-blue clay, of great tenacity, and
containing regular layers of large septaria.   These septaria are com-
posed of argillaceous limestone, of a very pale, almost white colour,
with thick septa of calcspar.   The contrast between this light-
coloured band and the darker beds above and below it is very striking.
The Cement-bed is well seen in the cliff, and can be easily traced
by the old workings from Speeton Gap, where its base is between
20 and 30 feet above high-water mark, to the place of its outcrop
near the northern extremity of Black Cliff.   It is also well seen in
the landslip at the base of the same cliff.   Both the septaria and the
clay of the Cement-bed are of considerable commercial value.   (*Vide*
Appendix C.)

This bed is crowded with fossils, which occur either mineralized
by pyrites and scattered through the clay, or enclosed in and re-
placed by the substance of the septaria.   Some of the fossils attain
a great size, as the large and nearly smooth species of *Ammonites*
(undescribed), and the so-called *Hamites maximus* (probably an
Ancyloceras) ; on one occasion I had an opportunity of seeing an
Ammonite (probably of a new species), imbedded in the soft clay
and incapable of removal, which measured three feet in diameter.

The total thickness of the highest division of the Speeton Clay is
certainly considerably above 100 feet.   Its fauna, as will be seen
from the subjoined list, is most unmistakeably that of the Lower
Greensand and Atherfield Clay of the south of England.

Fossils of the Upper Neocomian of Speeton.

r. Plesiosaurus (vertebræ and paddle-bones).	C. Belemnites semicanaliculatus (*Blain.* ?).
R. Teleosaurus (skull).	c. —— minimus ?, *List.*
c. Teeth of Lamna.	c. —— ultimus ?, *D'Orb.*
c. Vertebræ and other remains of fishes.	C. Ammonites Deshayesii, *Leym.*
R. Obscure crustacean remains.	R. —— ——, var. curvinodus, *Phil.*
? Meyeria Vectensis.	c. —— Nisus, *D'Orb.*
R. Plate of Cirripede.	c. —— nucleus, *Phil.*
R. Nautilus pseudo-elegans, *D'Orb.*	c. —— marginatus, *Phil.*
r. —— radiatus, *Sow.*	r. —— rotula, *Sow.*
r. —— plicatus, *Sow.*	C. —— (spec. nov?).
	R. —— spec. nov.

  * Throughout this paper the letters affixed to the species indicate their rela-
tive abundance in the bed : c signifying *common,* C *very common,* r *somewhat
rare,* and R *very rare.*

R. Ammonites, spec. nov.
c. Ancyloceras grandis, *Forbes,* sp.
C. ——, spec.
c. ——, spec.
C. Rostellaria Parkinsoni, *Phil.* (non *Sow.*).
C. —— bicarinata, *Leym.*
r. Cerithium Clementinum, *D'Orb.*, var.
r. Turritella lævigata, *Leym.*
r. Solarium (?) tabulatum, *Phil.*
c. Trochus (?) pulcherrimus, *Phil.* sp.
C. —— (?) granulatus, *Bean,* MS.
r. Pleurotomaria provincialis, *D'Orb.* sp.
r. ——, sp.
c. Auricula (?) obsoleta, *Phil.*
r. Delphinula ? (*Phil.*).
R. Emarginula Neocomiensis, *D'Orb.*
r. Dentalium ellipticum ? *Sow.*(casts).
R. Ostrea Leymeriei, *D'Orb.*
r. —— frons, *Park.*
c. Exogyra sinuata, *Sow.* (normal form).
r. —— parvula, *Leym.*
r. ——, sp.
r. Placunopsis, sp.
c. Pecten elongatus, *Lam.*
C. —— orbicularis, *Sow.*
r. —— cinctus, *Sow.* (dwarfed var.).
R. —— interstriatus, *Leym.*
R. —— striato-punctatus, *Röm.*
c. Lima, spec. nov.
c. ——, spec. nov.
r. —— undata, *Desh.*
r. —— elegans, *Duj.*
r. Plicatula placunea, *Lam.,* var.
c. Avicula, spec. nov.
r. Gervillia anceps ?, *Desh.*
c. Perna Mulletii, *Desh.*
c. Inoceramus venustulus, *Bean, MS.*
r. —— concentricus ?, *Sow.* (small var.).
r. —— imbricatus, *Bean, MS.*
r. Pinna gracilis, *Phil.*
r. Cucullæa securis, var. major, *Leym.*
C. Nucula obtusa, *Sow.*
C. —— ——, var. planata, *Desh.*
c. —— (Leda ?) subrecurva, *Phil.* (N. scapha, *D'Orb.*).
r. Corbis, sp.
r. Astarte lævis, *Phil.*
r. —— laticosta, *Desh.*
C. Isocardia angulata, *Phil.*
r. —— (?) sp.
? Trigonia spinosa, *Park.*
c. Mya (?) phaseolina, *Phil.*
c. Thetis Sowerbyi, *Röm.,* var. minor, *Sow.*
r. —— ——, var. major, *Sow.*
c. Panopæa plicata, *Sow.*

Fig. 1.—*Diagrammatic Section illustrating the relations of the beds exposed in Filey Bay.*
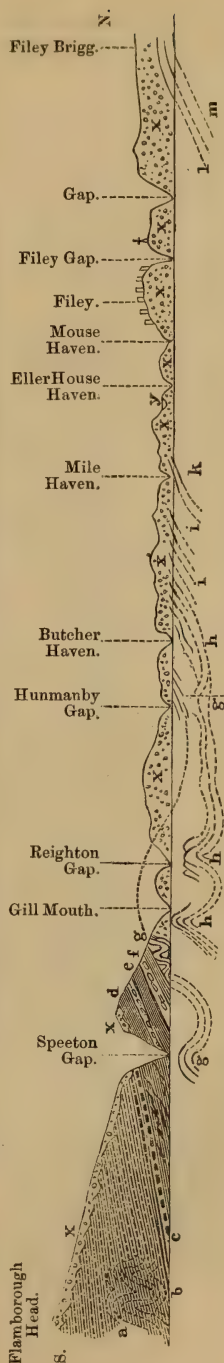
a. White chalk. *b.* Chalk with red bands. *c.* Hunstanton Limestone. *d.* Upper Neocomian. *e.* Middle Neocomian. *f.* Lower Neocomian. *g.* Portlandian. *h.* Upper Kimmeridge. *i.* Middle Kimmeridge. *k.* Lower Kimmeridge. *l.* Coral Rag. *m.* Lower Calcareous Grit. *x.* Drift. *y.* Freshwater deposit.

C. Panopæa Neocomiensis, *Desh.*
C. Thracia Phillipsii, *Röm.*, var.
c. Pholadomya Martini, *Forbes.*
c. Pholadomya, sp.
r. ——, sp.
c. Pholas constricta, *Phil.*
r. Teredo, sp.
c. Serpula articulata, *Sow.*
c. —— filiformis, *Sow.*
r. —— antiquata, *Sow.*
C. Vermicularia Phillipsii, *Röm.* sp.
R. —— —— (reversed variety).
c. Terebratula sella, *Sow.*
r. —— depressa?, *Lam.*

R. Terebratulina striata, *Wahl.* (var.
    pentagonalis, *Phil.*).
r. Rhynchonella sulcata, *Park.*
R. —— lineolata, *Phil.* sp.
R. ——, spec. nov. ?
R. Discina, spec. nov.
r. Lingula truncata, *Sow.*
c. Cidaris, sp.
c. Pseudodiadema, sp.
c. Pentacrinus angulatus, *Röm.*
r. Trochocyathus conulus?, *Phil.*
r. Sponges.
C. Wood.

Every one who compares the foregoing list of fossils with those of the Lower Greensand and its equivalents must be struck with their general agreement, especially with regard to those species which are most highly characteristic, and have the widest geographical range. The difference of the conditions under which the two series were deposited and the distance of their localities will be amply sufficient to account for the differences between their fossil contents. Professor Edward Forbes has furnished us[*] with an elaborate analysis and comparison of the fossils of the different beds of the Lower Greensand, and has demonstrated that the whole series contains but one fauna, by showing that whenever the same physical conditions are repeated, the same species of fossils recur. It is this fauna which we find in the highest division of the Speeton Clay; and as the beds of clay which lie at the base of the Lower Greensand most nearly resemble in lithological character the beds we are describing, it is of course in these (the Atherfield Clay) that we must look for the closest analogies with the fossils of the Yorkshire beds.

The relations of the Lower Greensand to various foreign deposits have been so fully and ably worked out by Dr. Fitton, Professor Forbes, and Mr. Godwin-Austen in this country, and by MM. Römer, D'Orbigny, and D'Archiac and others on the continent, that it will be quite unnecessary for me to enter upon the subject. It may, however, be well to point out that this highest division of the Speeton Clay appears to be altogether unrepresented in the *Hilsthon* and *Hilsconglomerat* of Römer, which are, as we shall hereafter show, by far the nearest continental equivalents of the second and third divisions of the Yorkshire deposit.

The name of "*Etage Aptien*," which was proposed by D'Orbigny for beds of this age, has been generally discarded by continental geologists in favour of the term "Upper Neocomian," which is certainly preferable; for I am convinced that the time is rapidly approaching when geologists will allow the claims of the vast series of beds between the Gault and Portlandian to rank, not merely as a subordinate member of the Cretaceous, but as a third Mesozoic *System* intermediate between the Cretaceous and Jurassic. In order to avoid the glaring solecism involved in calling beds of blue clay "Lower Greensand," I have used the continental term.

* Quart. Journ. Geol. Soc. vol. i. (1845) p. 194 &c.

Fig. 2.—*Cliff-section at Speeton. Scale* 12 *inches to a mile.*
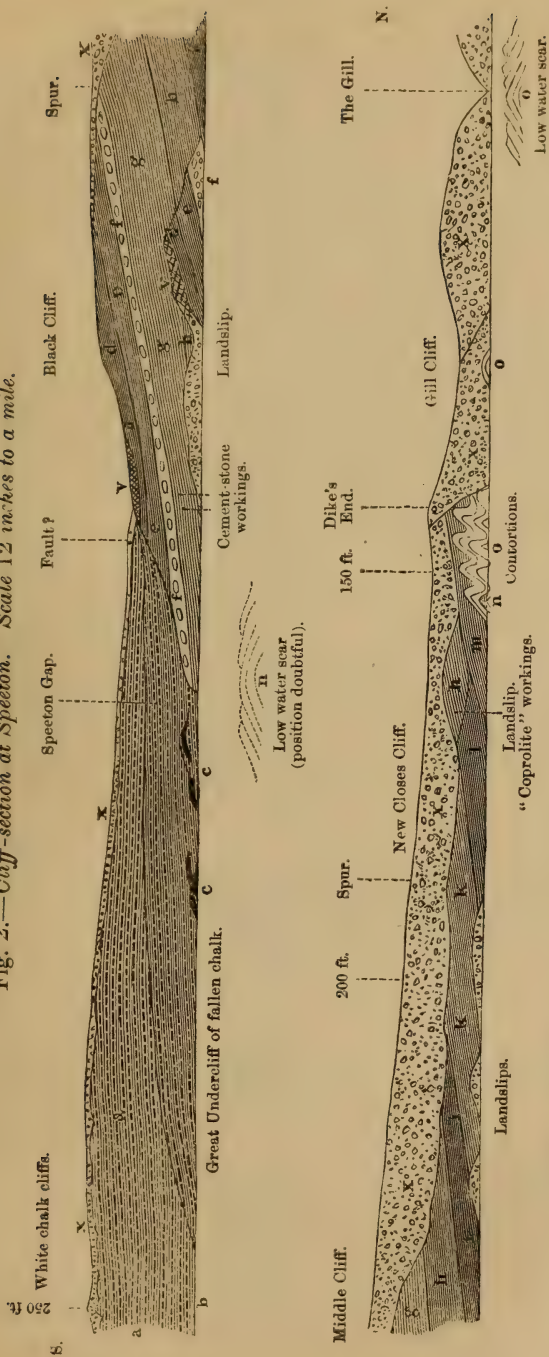
a. White chalk. b. Chalk with coloured bands. c. Hunstanton Limestone. d, e. Dark-blue clays. f. Cement beds. g. Blue clays. h. *Pecten cinctus* beds. i. Ancyloceras-bed. k. Speetonensis-bed. l. Noricus-bed. m. Astierianus-bed. n. Portlandian beds. o. Upper Kimmeridge beds. v. White and red chalk rubble. x. Drift.

Fig. 3.—Sketch-map of Speeton Cliff (1867).   Scale 9 inches to 1 mile.

c. Hunstanton Limestone.   d. e. Dark-blue clays.   f. Cement beds.   g. Blue clays.   h. Pecten cinctus beds.   i. Ancyloceras beds.
k. Speetonensis-bed.   l. Noricus-bed.   m. Asterianus-bed.   n. Portlandian beds.   o. Upper Kimmeridge beds.   v. White and
red chalk rubble.   x. Drift.

Fig. 4.— *Vertical Section, showing the subdivisions of the Speeton Clay.*

Upper Greensand (?).	Hunstanton Limestone, 30 ft.	Unconformity. *Belemnites* (no other fossils).
Upper Neocomian, 150 ft. + .	Black clays	
	Dark-blue clays	*Belemnites semicanaliculatus, Rhynchonella sulcata, Park.*
	"Cement beds," 30 ft....	*Perna Mulletii*, Desh., *Exogyra sinuata, Pecten elongata, P. orbicularis.—Am. Deshayesii*, am., sp., *Bel. semicanaliculatus, Ancyloceras?* grandis. — *Thetis Sowerbyi, Panopœa plicata, P. Neocomiensis, Alaria, Vermicularia Sowerbyi.—Terebratula sella, &c. &c.*
Middle Neocomian, 150 ft. ...	Dark-blue clays, 80 ft...	Very few fossils.
		Bel. jaculum (rare), &c.
	Zone of *Pecten cinctus* (Sow.), 40 ft.	*Pecten cinctus* (large var.), *Exogyra sinuata* (normal form), *Ammonites, Ancyloceras Duvalii, Bel. jaculum*, &c. &c., *Terebratula depressa, Meyeria ornata.*
	"Shrimp-bed".............	
	Ancyloceras-beds, 30 ft.	*Ancyloceras Duvalii, An. Emericii, Waldheimia Celtica, Ammonites bipinnatus,* Will. MS.
Lower Neocomian, 200 ft. + .	Zone of *Am. Speetonensis,* Y. & B., (clays) 100 ft.	*Am. Speetonensis* (varieties), *Am. rotula, Am. Nisus,* &c. *Bel. jaculum, Cerithium,* sp., *Trochus,* sp., *Bel.; Exogyra subplicata, Thracia Phillipsii, Pholadomya,* sp.; *Waldheimia Celtica, Pholas constricta, Serpula articulata,* &c.
		Ancyloceras Puzosianum, An. Duvalii, An. Emericii.
	Zone of *Am. Noricus,* Schloth. (clays), 50 ft.	*Am. Noricus* (varieties), *Am. marginatus.*
		Ancyloceras Puzosianum, Bel. jaculum (rare).
	Zone of *Am. Astierianus,* d'Orb. (pyritic clays)	*Am. Astierianus, Am. multiplicatus, Am. hystrix,* &c.; *Bel. lateralis.*
		Exogyra subsinuata (varieties).
		Toxaster complanatus.
Portlandian ...	"Coprolite-bed "	*Lucina Portlandica, Lithodomus, Arca, Nucula, Ammonites, Saurians.*
	Fish-bed	
	Clays and hard dark-coloured rock-bands	*Ammonites gigas, Am. Gravesianus, Am. giganteus?.*
Upper Kimmeridge.............	Laminated bituminous clays and slaty beds	*Am. biplex* (others of group " *Planulati* "), *Discina latissima, Lingula ovalis, Cardium, Inoceramus, Ostrea* &c. &c.
Middle Kimmeridge	Light-blue sandy, and dark-blue pyritic clays	*Ammonites mutabilis, Am. triplicatus, Am. biplex. Belemnites. Ceromya excentrica?, Pinna granulata, Modiola, Leda, Pholadomya, Myacites,* &c.
Lower Kimmeridge.............	Dark-coloured clays ...	*Ammonites alternans, Rhynchonella inconstans.*
Lowest beds of Kimmeridge . Upper Calcareous Grit ...	Not seen	
Coral Rag (only few feet seen)		
Lower Calcareous Grit........................		

B. *Middle Neocomian.*—The second division of the Speeton Clay is seen lying immediately below the "Cement-beds," in the northern part of Black Cliff and the southern part of Middle Cliff. On the spur between these two cliffs, which affords special facilities for their study, the beds of this division are found to extend from a height of 20 feet up to 170 feet above high-water mark, and are therefore about 150 feet thick.

Directly below the "Cement-beds" we find a great thickness (80 feet) of dark-blue clays, containing but few septaria, and these apparently not occurring in definite layers. Throughout this bed fossils are extremely rare. They are of the following species:—

R. Belemnites semicanaliculatus?, *Blainv.*	r. Vermicularia Phillipsii, *Röm.* sp.
R. —— jaculum, *Phil.*	r. Pecten cinctus, *Sow.* (large form).
R. ——, sp.	r. Exogyra sinuata, *Sow.* (typical form).

These beds are underlain by others of similar lithological character but much more fossiliferous, which are about 40 feet thick; they are characterized by the great abundance of the gigantic form of *Pecten cinctus*, of *Exogyra sinuata* (the typical form, often of great size), and of *Belemnites jaculum*. Owing to the circumstance of their being enclosed in clay, it is rarely that we find perfect specimens of the *Exogyræ* and *Pectines*, though their fragments are extremely numerous.

In the lower part of this mass of clay there occur several layers of small dark-brown nodules with pyritous septa. In one of these seams almost every nodule contains a specimen, more or less perfect, of the *Meyeria ornata*, Phil. sp. This is the "Shrimp-bed" of collectors. In larger scattered nodules in the same portion of the bed there occur specimens of a large undescribed Ammonite (*A. bipinnatus*, Will. MS.) and of *Ancyloceras Duvalii*, Léveillé. This portion of the series may be well studied in Middle Cliff, and also in New Closes Cliff, where it is brought down by a landslip.

The base of the second division of the Speeton Clay is formed by a bed of dark-blue clay, distinguished by containing regular layers of septaria, which are of a light-brown colour, and contain specimens of *Ancyloceras* and *Ammonites*. As this is the horizon at which the former fossils attain their maximum of abundance, we may appropriately call this bed "the Ancyloceras-bed." It is likewise the metropolis of *Belemnites jaculum*.

Fossils from the Middle Neocomian of Speeton.

r. Vertebræ and teeth of fishes.	R. Ammonites cryptoceras, *D'Orb.*
R. Belemnites semicanaliculatus?, *Blainv.*	R. —— crassicostatus, *D'Orb.*
	R. —— angulicostatus, *D'Orb.*
r. ——, sp.	C. Ancyloceras (Crioceras) Duvalii, *Léveillé.*
C. —— jaculum, *Phil.*	
c. Ammonites bipinnatus, *Will. MS.*	C. —— (Crioceras) Emericii, *Léveillé.*
c. —— marginatus, *Phil.*	r. ——, sp.
r. —— nucleus, *Phil.*	C. Meyeria ornata, *Phil.* sp.
r. —— Nisus, *D'Orb.*	r. Other crustacean remains.
c. —— rotula, *Sow.*	r. Cerithium Phillipsii, *Leym.*

r. Cerithium, sp.
r. Trochus, sp.
r. Ostrea frons, *Park.*
C. Exogyra sinuata, *Sow.* (typical form).
c. —— —— (var. elongata, *Leym.*).
C. Pecten cinctus, *Sow.* (gigantic form).
r. Lima, spec. nov.
r. Nucula obtusa, *Sow.*
R. Lucina sculpta, *Phil.*
r. —— crassa, *Sow.*
c. Pholadomya Martini, *Forbes.*
r. ——, sp.
c. Thracia Phillipsii, *Röm.*

c. Panopæa Neocomiensis, *Desh.* sp.
r. Terebratula depressa ?, *Lam.*, var.
? Terebratula hippopus, *Röm.*
r. Waldheimia Celtica, *Morris.*
r. Rhynchonella sulcata, *Park.*
c. Serpula filiformis, *Sow.*
c. —— antiquata, *Sow.*
r. —— gastrochænoides, *Leym.*
c. ——, sp.
r. Vermicularia Phillipsii, *Röm.*
r. Pentacrinus angulatus, *Röm.*
r. Pentacrinus, sp.
Sponges.
Cliona (crypts).
Wood.

In a paper which I had the honour of submitting to this Society during its last session*, I showed that certain beds in Lincolnshire, for which I proposed the name of the "Tealby Series," are of Middle-Neocomian age, and also pointed out the correspondence which exists between those beds and the portion of the Speeton Clay we are now discussing. This correspondence is especially seen in the abundance in both these series of gigantic specimens of *Pecten cinctus* and *Exogyra sinuata*, as also by the presence of *Belemnites jaculum*, an undescribed Ammonite (*A. bipinnatus*, Will. MS.), the same species of *Ancyloceras*, with other fossils. It is true that the Clypeiform Ammonites, which are so very characteristic of the Lincolnshire series and some of its continental equivalents, have not hitherto, so far as I am aware, been found in this division of the Speeton Clay; but so close is the correspondence in other respects that I am sanguine of these fossils being sooner or later discovered in the Yorkshire beds.

If we now turn our attention to the continental deposits which appear from palæontological evidence to be the equivalents of this division of the Speeton Clay, that which claims our first attention is the *Hilsthon* of Hanover and Brunswick. The sections of these strata being all inland, the succession of beds does not appear to have been worked out in any detail; but a reference to the description of this formation by M. Römer†, and to that, of a later date, by M. von Strombeck‡, will suffice to show its very close agreement with our second and third divisions of the Speeton Clay. As far as can be judged from these descriptions, the upper part of the Hilsthon represents the Middle Neocomian, and is the equivalent of the beds at Speeton which I have just described. The lower part of the Hilsthon and the whole of the Hilsconglomerat, on the other hand, seem referable to the Lower Neocomian, and correspond to the third division of the Speeton Clay.

In the thin belt of Neocomian strata which surrounds the Paris basin, and has been made known to us by the admirable researches

* Quart. Journ. Geol. Soc. vol. xxiii. p. 227.
† Verst. nordd. Kreide (1840–41).
‡ Ueber die Neocomien-Bildung, &c.—Zeitschrift d. geol. Gesellsch. vol. i. p. 462 (1849); Leonhard und Bronn's Jahrb. Min. 1850, p. 230.

of MM. Leymerie, Cornuel, Longuemar, D'Archiac, and others, the middle division of the Neocomian would appear to be much less perfectly represented than either the upper or lower divisions.

When we pass beyond the limits of the Anglo-Parisian basin, the difficulty of correlating the different foreign deposits with our Yorkshire beds becomes, as might be expected, greatly increased, the more so from the wide discrepancies of opinion which exist among French geologists concerning the true stratigraphical relations of some of their beds. Without, however, trespassing on these fields of controversy, I may state that the extensive series of deposits, consisting principally of *white* limestones, which overlie the true Neocomian limestones (which are generally of a *yellow* colour) in Switzerland and South-eastern France, and are especially characterized by the abundance of *Chama Ammonia* and other species of *Rudistes*, appear to represent the Middle Neocomian and that part of the Speeton Clay which I have been describing.

Other deposits, which appear to be of the same age, exist in the south of Spain, the north of Italy, in Austria, in the province of Constantine in Northern Africa, and probably in New Granada.

C. *Lower Neocomian.*—The third division of the Speeton Clay is seen at the lower portions of Middle and New Closes Cliffs, the upper parts of these cliffs being entirely concealed by drift. In subdividing this series of beds, I shall avail myself of the limited vertical ranges of several groups of Ammonites found in it. The sections into which the series thus naturally falls are as follows :—

a. Zone of Ammonites Speetonensis, *Y. & B.*—This consists of about 100 feet of dark-blue clays, containing fossils in the form of pyritous casts, *Ammonites* being particularly abundant. The prevailing species is that which gives its name to the bed, and which is, as far as I yet know, perfectly characteristic of it. *Belemnites jaculum* is still abundant throughout this bed ; and towards its lower part occur specimens of *Ancyloceras*, either enclosed in claystone nodules or mineralized by pyrites. *Exogyra sinuata*, of the typical form, is found but rarely in this bed ; but the little variety called *E. subplicata* by Römer occurs, and is, I believe, entirely confined to this zone.

b. Zone of Ammonites Noricus, *Schloth.*—This bed, like the last, which it resembles in lithological characters, is very well characterized by a group of *Ammonites*. *Belemnites jaculum* here becomes exceedingly rare, as do also the species of *Ancyloceras* ; in the whole of this bed, which is about 50 feet thick, I have been able to obtain but a comparatively small number of species of fossils.

c. Zone of Ammonites Astierianus, *D'Orb.*—The lowest beds of the Neocomian series at Speeton are extremely well marked, both by their lithology and by their palæontology. They consist of from 50 to 100 feet of dark-coloured shaly clay, highly impregnated with pyrites. Unfortunately, owing to this last circumstance, all the smaller and more delicate fossils are rapidly destroyed by the action of the air. This bed may always be easily recognized by its shaly character, and by its fragments being constantly coated with a yellowish-white efflorescence, consisting of basic sulphate of iron.

Fossils from the Lower Neocomian of Speeton.

	Zone of Am. Speetonensis.	Zone of Am. Noricus.	Zone of Am. Astierianus.
Teeth of Lamna	*r.*		
Vertebræ of fish	*c.*	*r.*	*r.*
Astacodes falcifer, *Phil.* sp.	*r.*		
Belemnites jaculum, *Phill.*	*r.*		
—— lateralis, *Phil.*	*r.*	*c.*	C.
Ammonites Speetonensis, *Y. & B.*			
—— ——, var. venustus, *Phil.*	C.		
—— ——, var. concinnus, *Phil.*	C.		
—— ——, other varieties	*c.*		
—— Noricus, *Schloth.* (varieties)	......	*c.*	
—— , var. ? furcillatus, *Bean, MS.*	......	*c.*	
—— Astierianus, *D'Orb.* (varieties)	......	R ?.	*r.*
—— multiplicatus, *Röm.*	......	......	*r.*
—— ——, var. ? hystrix, *Phil.*	......	......	R.
—— Nisus, *D'Orb.*	*r.*		
—— rotula, *Sow.*	*c.*	*r.*	
—— trisulcosus (?), *Phil.*	*r.*		
—— marginatus, *Phil.*	*c.*	*c.*	
—— nucleus, *Phil.*	*r.*		
——, sp.	*r.*		
Ancyloceras (Crioceras) Duvalii, *Léveillé*	*c.*	*r.*	
—— (Crioceras) Emericii, *Léveillé*	*c.*	*r.*	
—— (Crioceras) Puzosianum, *D'Orb.?*	*r.*	*c.*	
—— (Hamites) raricostatum, *Phil.*	......	*c.*	
Cerithium aculeatum	*r.*		
Trochus, sp.	*r.*		
Dentalium lævigatum, *Bean, MS.*	*r.*		
Exogyra sinuata, *Sow.* (typical form).	*r.*		
—— subplicata, *Röm.*	*c.*		
—— Couloni (E. subsinuata, *Leym.*)	......	......	C.
—— ——, var. dorsata, *Leym.*	......	......	C.
—— ——, var. falciformis, *Goldf.*	......	......	C.
—— ——, var. aquilina, *Leym.*	......	......	*r.*
Ostrea, sp.	*r.*	*r.*	
Pecten cinctus, *Sow.* (gigantic form)	R.		
Nucula obtusa, *Sow.*	*r.*		
—— (Leda ?) subrecurva, *Phil.* (N. scapha, *D'Orb.*)	*r.*		
Astarte laticosta, *Desh.*	*r.*	?	
Pholadomya, sp.	*r.*		
Thracia Phillipsii, *Röm.*	*c.*	*r.*	
Pholas constricta, *Phil.*	*r.*	*r.*	
Teredo, sp.	*r.*	......	*r.*
Terebratula depressa ?, *Lam.*	*r.*		
Rhynchonella sulcata, *Park.*	*r.*		
Serpula articulata	*r.*		
Toxaster complanatus, *Ag.*	......	......	R.
Pentacrinus, sp.	*r.*		
Wood	*r.*	*r.*	
Frond of Fern (*Lonchopteris ?*)	......	......	R.

Palæontologically, this division is distinguished by the presence of *Ammonites Astierianus* and its allies, though I believe rare specimens

of these occasionally occur in the bed above. *Belemnites jaculum* has now entirely disappeared, and its place is taken by *Belemnites lateralis*, which occurs in prodigious numbers, and in every stage of growth. But the most abundant and strikingly characteristic fossil of this bed is that form (subspecies of Leymerie) of *Exogyra sinuata* (the large and typical form of which never occurs) which is called *E. subsinuata* or *E. Couloni*, and is likewise so abundant in and characteristic of the Neocomian Limestone of Central and South-eastern France. A solitary specimen of an Echinoderm, *Toxaster complanatus*, which is equally characteristic of those continental deposits, was probably also obtained from this lowest division of the Speeton clay.

In my previous paper on the beds of Lincolnshire I abstained from any attempt at correlating the beds below the Tealby series, on account of the paucity and imperfection of their fossils; but I pointed out that the Carstone of Norfolk and Cambridgeshire represents the upper and lower sandy series of Lincolnshire, the intermediate limestone and ironstone series having entirely thinned out. I may now state that the fossils of the lower sand and sandstone of Lincolnshire, as well as those of the lower portion of the Carstone of Norfolk, all point to the conclusion that these beds are of Lower-Neocomian age; and this view has been confirmed in the most striking manner by the discovery of the richly fossiliferous deposits of Upware and Potton. Among the fossils from those localities I find the different varieties of *Ammonites Speetonensis* and *Am. Noricus*, a large number of Lower-Neocomian species of Brachiopoda, and not a few bivalves and univalves occurring in the same formation.

I have already pointed out the very striking correspondence between the lower division of the Speeton Clay and the lower part of the Hilsthon and the Hilsconglomerat of North-western Germany, a correspondence which is sufficiently accounted for when we take into consideration the resemblance in petrological character between the two formations, and also their geographical relations.

Less numerous, but still most unmistakeable, are the points of analogy between these beds and the Lower-Neocomian limestones of the Paris basin (*Calcaire à spatangues* of Leymerie) and the enormous deposits of yellow limestone of Provence and Switzerland, the *original* Neocomian Limestone (Calcaire Neocomien à *Toxaster complanatus* of D'Archiac). The presence in the Yorkshire bed of such eminently characteristic species as *Exogyra Couloni*, *Toxaster complanatus*, *Ammonites Astierianus*, *Ammonites Noricus*, *Belemnites lateralis*, and others, leaves nothing further to be desired in establishing this correlation. The present state of our knowledge of these foreign beds will not warrant any attempt at drawing a parallelism between their subdivisions and the very distinct zones of their Yorkshire representative, though such a parallelism may at some future period be shown to exist.

Other very extensive deposits of this age occur, as is well known, in Spain, Italy, Austria, the Crimea and Caucasus, Northern Africa, and South America. In a collection of Neocomian fossils from

Bogotá which was shown to me by Mr. Woodward of the British Museum, I noticed undoubted specimens of *Ammonites Astierianus* and *Exogyra subsinuata*, evidently from the same deposit.

D. *Portlandian.*—The junction of the Neocomian and Jurassic beds at Speeton is indicated (as is so frequently the case when two distinct formations are seen in apposition) by a layer of phosphatic nodules and saurian remains. For first pointing out this very interesting fact we are indebted to Mr. Leckenby[*]. I am also inclined to believe that the break is still further marked by an unconformity between the comparatively slightly disturbed Neocomian beds and the highly contorted Upper Jurassic. Unfortunately the present state of the section will not permit of our arriving at any definite conclusion on this point.

The Jurassic beds of Filey Bay do not afford the same facilities for their study as those already described; and we have to be satisfied with only slight and occasional exposures of them. This circumstance, however, is the less to be regretted, as, with the exception of the highest zone, they are all very completely represented in other parts of England.

This highest zone, which Mr. Leckenby considers referable to the Portlandian—an opinion in which I fully concur—consists of three portions. The uppermost of these is formed by the bed of phosphatic nodules (" Coprolite-bed " of the workmen), and is seen on the shore below the cliff when it has been bared of sand and shingle by storms. It also reappears under similar circumstances on the shore near Hunmanby Gap, a mile to the north of the last-mentioned locality, into which position it is brought by the enormous contortions to which these beds have been subjected. At the lower part of New Closes Cliff the " Coprolite bed " again occurs, and is there extensively worked (*vide* Appendix C). The bed, which averages only 5 inches in thickness, consists of very dark-coloured heavy nodules of phosphatic matter much mixed with pyrites. It contains numerous casts of shells, of a black colour and much eroded, and not unfrequently bones of saurians. Some years ago the nearly perfect skeleton of a *Plesiosaurus* was found in this bed, a portion of which is now in the possession of Lord Londesborough. The fossils of this bed are as follows :—

Ammonites gigas, *Zeit.*	Lithodomus (crypts).
—— rotundus, *Sow.*	(Other indeterminate casts.)
Lucina Portlandica, *Sow.*	Wood.
Arca (casts).	Bones of Saurians and Fish.
Nucula (casts).	

Below the " Coprolite bed " occurs a layer of peaty clay containing fish-remains. This bed is now entirely concealed, and I am indebted to Mr. Leckenby for information as to its true position.

The lowest and principal portion of the Portlandian at Speeton consists of dark-coloured clays, with hard stony bands. These cannot be seen in the cliff, owing to the workings which have been

* Wright's Mon. Brit. Cret. Echin. (1864) p. 9.

carried on there; but from those workings fragments of their fossils are sometimes brought out. Mr. Leckenby, however, informs me that, after a long prevalence of south-westerly gales, these beds may be seen on the shore near low-water mark, and opposite to the cliff; and that he has himself obtained from them in that spot the characteristic Ammonites. Having never had the good fortune to gain a sight of these rocks, I have been unable to fix their exact position on my map. The only fossils I am acquainted with from these beds are, the very highly characteristic coronated Ammonites, viz. *A. gigas*, Zeit., and *A. Gravesianus*, D'Orb., together with *A. rotundus*, Sow., and comparatively small specimens of *Ammonites giganteus*, Sow.? At one time these fossils could frequently be collected from blocks on the shore of Filey Bay; but owing to the constant removal of material for road-metal, I believe that they are now seldom so met with.

Fossils of the Portlandian of Speeton.

r. Belemnites, sp.
c. Ammonites gigas, *Ziet.*
c. —— Gravesianus, *D' Orb.*
r. —— Irius, *D' Orb.*
c. —— giganteus, *Sow.*?
C. —— rotundus, *Sow.*
c. Arca (casts).
c. Nucula (casts).
C. Lucina Portlandica, *Sow.*
r. Lithodomus (crypts).
Wood.
Plesiosaurus.
Other fish-remains.

Although, as will be seen from the foregoing list, the actual number of species obtained from this series is but small (and in no district has an extensive fauna been obtained from beds of Portlandian age), yet the presence of the eminently characteristic species of coronated Ammonites (not to mention any others), taken in connexion with the stratigraphical relations of the beds, is, I believe, sufficient warrant for the correlation of them proposed by Mr. Leckenby. A very close correspondence between the fossils of these beds of clay and those of the well-known Portland limestone and sand of the South of England would scarcely be anticipated; and accordingly we are not surprised to find closer analogies in the fauna of beds of the same age in the Jura of France and Switzerland,—beds which, though at a greater geographical distance, yet agree much more nearly with them in lithological characters.

E. *Upper Kimmeridge.*—This series of beds is, like the last, but very imperfectly exhibited in Filey Bay. Fragments of it are brought out from some of the coprolite workings; and a small portion of it *in situ*, exhibiting great contortions, was exposed in November 1867, to the north of New Close Cliff, by a landslip in the drift. But by far the best exposure in these beds is that which I had the opportunity of observing in May 1867*, when, part of the shore, opposite to Raincliff Gill, being bared of shingle and sand, a portion of these beds, forming the denuded summit of an anticlinal, was uncovered, and could be examined during low water

* Professor Phillips appears to have witnessed a similar exposure of the same beds in 1826. Geology of Yorkshire, 2nd edition (1835), p. 48.

at the spring tides.   Waterworn fragments of this bed are also constantly thrown up on the shore of the bay.   This group consists of very finely laminated, dark-coloured, bituminous clay, or rather shale, interstratified with hard slaty beds, occasional septaria being scattered through the mass.   The beds are crowded with fossils, which, however, are always compressed between the laminæ, and are seldom capable either of identification or preservation.   The Ammonites, which are particularly abundant, are referable to *A. biplex*, Sow., and other species of the group of *Planulati*, which are characteristic of the continental White Jura.   *Discina latissima*, Sow. sp., *Lingula ovalis*, Sow., with many bivalves, and some univalves, also occur in great abundance.

Fossils of the Upper Kimmeridge of Speeton.

c. Icthyosaurus (vertebræ).	*c.* Innoceramus, sp.
C. Ammonites biplex, *Sow.*	*c.* Cardium, sp.
C. ——. Several species of the group of *Planulati*, but too much crushed for identification.	(Numerous species of bivalves).
	C. Discina latissima, *Sow.* sp.
	C. Lingula ovalis, *Sow.*
r. Ostrea, sp.	

In pointing out the relations of this division of the Speeton Clay, I may be permitted to call attention to the very admirable classification of the Kimmeridge beds, proposed by Dr. Waagen * in 1865. Having had the opportunity of comparing this classification, not only with the beds of Ringstead Bay in Dorsetshire, which the author employs as his typical section, but also with the Kimmeridge of Lincolnshire, which is very extensively and completely developed, and now with the equivalent beds in Yorkshire, I am convinced that no other arrangement hitherto proposed represents so faithfully, at least as far as this country is concerned, the true palæontological relations of the Upper Jurassic strata.

The laminated bituminous clays which I have described as occurring at Speeton agree very closely, both in mineral characters and in their fossils, with the Upper Kimmeridge (Region of *Discina latissima* and *Acanthoteuthis speciosa* of Dr. Waagen) of Dorsetshire and Lincolnshire.   Everywhere these beds are characterized by the abundance of *Discina latissima* †, *Lingula ovalis*, and certain Ammonites of the group of the *Planulati*.

F. *Middle Kimmeridge*—The beds of this zone are exposed at a number of places in the cliff, commencing near Mile Haven, and extending along the shore for about a mile to the southwards. They consist of light-blue, somewhat sandy clay, of the kind called by workmen "dicey"—that is, breaking up into more or less regular quadrangular fragments ; a few septaria are scattered through this clay.   Towards the upper part the beds become darker in colour, laminated in structure, and frequently contain much pyrites.

* Versuch einer allgemeinen Classification der Schichten des oberen Jura. München, 1865.

† Sowerby's original specimens of *Discina (Patella) latissima* were obtained from beds similar to those I have been describing, at Bolingbroke, Lincolnshire.

Fossils of the Middle Kimmeridge of Filey Bay.

c. Belemnites Trosloyanus, *D'Orb.*
C. —— nitidus, *Dollfuss.*
c. Ammonites mutabilis, *Sow.*
c. —— biplex, *Sow.*
r. —— triplicatus, *Sow.*
r. —— Marantianus?, *D'Orb.*
r. —— Yo? *D'Orb* (juv.).
r. —— Berryeri?, *Lesueur.*
r. ——, sp.
r. Ancyloceras?, sp.
r. Ostrea, sp.
C. Exogyra virgula, *Defr.* (var.).
C. —— nana, *Sow.*
r. Plicatula, sp.

c. Pecten, sp.
c. Pinna granulata, *Sow.*
r. Modiola bipartita,*Phil.*(non *Sow.*).
r. Leda, sp.
r. Ceromya excentrica?, *Ag.*
c. Myacites, sp.
c. Pholadomya, sp.
? Thracia depressa, *Sow.*
r. Rhynchonella, sp.
r. Pentacrinus, sp.
c. Sponges.
C. Wood, both in the state of jet and
         mineralized by pyrites.

Not less satisfactory than in the preceding case, is the identification of these beds with the Middle Kimmeridge (Region of *Ammonites mutabilis* and *Exogyra virgula* of Dr. Waagen). The different beds of this age present many features of very great interest, but have never received that amount of attention which they deserve; in Lincolnshire they furnish a large and well-marked fauna, being exposed in a number of clay-pits (of which I may especially instance those of Horncastle and Usselby *), and also in the Wrawby cutting of the Manchester, Sheffield, and Lincolnshire Railway. The uniformity of character in the Kimmeridge clay, as seen in Dorsetshire, Lincolnshire, and Yorkshire, is very striking.

G. *Lower Kimmeridge.*—Near Mile Haven, according to the testimony of fossil-collectors and others, certain beds of blue clay were at one time exposed, the septaria of which yielded a different series of fossils from those of the beds last described; among the fossils so obtained, I have seen undoubted specimens of *Ammonites alternans*, Von Buch, and *Rhynchonella inconstans*, Sow.

Dr. Waagen's lower division of the Kimmeridge Clay appears, at all events in Lincolnshire, to be divisible into two well-marked zones. In the upper of these, which may be well studied in the clay-pits about Market Rasen, *Ostrea deltoidea* never, I believe, occurs, while in the lower, which is well seen in a pit at Woodhall, that fossil occurs in prodigious numbers. A number of other palæontological characters also assist us in separating these two zones. The beds seen in Filey Bay appear to be referable to the upper of these; but the lower would seem, from a statement of Professor Phillips, to be found inland at Elloughton †.

No other deposits of Mesozoic age are seen in Filey Bay, until we arrive at the Brigg, where, as is well known, the Lower Calcareous Grit, covered by a few feet only of the Coral Rag, rises above the sea-level, and is seen in the cliff below the Boulder-clay.

VI. Conclusion.

In bringing this paper to a close, it may be well to recapitulate briefly the results arrived at. They are as follows:—

_____

* This pit is now, I believe, closed.   † Geology of Yorkshire, p. 46.

1. The Speeton Clay, including under this name all the beds of clay exposed in Filey Bay and intermediate between the Hunstanton Limestone and Coralline Oolite, is a deposit of very great thickness and importance.

2. It is certainly not the equivalent of the Gault; nor does any portion of it appear to be referable to that formation, the evidence on which it was thus originally correlated breaking down on reexamination, and being entirely negatived by other and ample evidence, both stratigraphical and palæontological.

3. The Speeton Clay contains at least seven divisions, well marked lithologically, still better defined palæontologically. They are :— 1st, the Upper Neocomian, having its equivalent in the Lower Greensand of the south of England ; 2nd, the Middle Neocomian, of which the Tealby series of Lincolnshire is the equivalent ; 3rd, the Lower Neocomian, now recognized for the first time in this country ; 4th, the Portlandian, agreeing much more closely with some of the continental representatives of that formation than with the limestone and sand of Portland ; and, 5th, 6th, and 7th, the Upper, Middle, and Lower Kimmeridge. Some of these groups fall naturally into still smaller subdivisions.

APPENDIX A.—*Table showing the Vertical Distribution of the Fossils of the Speeton Clay.*

	Upper Neocomian.	Middle Neocomian.	Lower Neocomian.	Portlandian.	Upper Kimmeridge.	Middle Kimmeridge.	Lower Kimmeridge.
Nautilus pseudo-elegans, *D' Orb*	r.						
—— radiatus, *Sow.*	r.						
—— plicatus, *Sow.*	r.						
Belemnites semicanaliculatus ?, *Blainv.*	C.	R.					
—— minimus, *List.*	?						
—— ultimus, *D'Orb*	?						
—— jaculum, *Phill.*	...	C.	r.				
—— spec. nov. ?	...	r.					
—— lateralis, *Phill.*	...	...	C.				
—— sp.	...	...	...	r.			
—— Trosloyanus, *D' Orb.*	...	...	...	...	...	c.	
—— nitidus, *Dollf.*	...	...	...	...	...	C.	
Ammonites Deshayesii, *Leym.*	C.						
—— ——, var. curvinodus, *Phill.*	R.						
—— Nisus, *D'Orb.*	c.	r.	r.				
—— nucleus, *Phill.*	c.	r.	r.				
—— marginatus, *Phill.*	c.	c.	c.				
—— rotula, *Sow.*	r.	c.	c.				
——, spec. nov. ?	C.						
——, spec. nov.	R.						
——, spec. nov.	R.						
—— bipinnatus, *Will. MS.*	c.						
—— cryptoceras, *D'Orb*	...	R.					
—— angulicostatus, *D'Orb*	...	R.	?				
—— crassicostatus, *D'Orb*	...	R.					

Table showing the Vertical Distribution (continued).

	Upper Neocomian.	Middle Neocomian.	Lower Neocomian.	Portlandian.	Upper Kimmeridge.	Middle Kimmeridge.	Lower Kimmeridge.
Ammonites Noricus, *Schloth.*	...	•••	c.				
—— ——, var. ? furcillatus, *Bean, MS.*...	...	...	c.				
—— Speetonensis, *Y. & B.*	...	...	C.				
—— ——, var. venustus, *Phill.*	...	...	C.				
—— ——, var. concinnus, *Phill.*	...	...	C.				
—— Astierianus, *D'Orb*	...	...	r.				
—— multiplicatus, *Röm.*	...	...	r.				
—— ——, var. ? hystrix, *Phill.*	...	...	R.				
—— trisulcosus, *Phill.*	...	...	r.				
——, spec. nov.	...	...	r.				
—— gigas, *Ziet.*	...	...	...	c.			
—— Gravesianus, *D'Orb.*	...	...	...	c.			
—— Irius, *D'Orb.*	...	...	...	r.			
—— giganteus, *Sow. ?*	...	...	...	c.			
—— rotundus, *Sow.*	...	...	•••	C.	C.	c.	
—— biplex, *Sow.*	...	...	...	c.	C.	c.	
—— mutabilis, *Sow.*	...	...	...	...	...	c.	
—— triplicatus, *Sow.*	...	...	...	...	•••	r.	
—— Marantianus, *D'Orb.*	...	...	...	...	...	r.	
—— Yo ?, *D'Orb.*	...	...	...	...	...	r.	
—— Berryeri ?, *Lesueur*	...	...	...	...	...	r.	
—— alternans, *Von Buch*	...	...	...	...	...	...	c.
Ancyloceras grande, *Forbes,* sp.	c.						
——, sp.	C.						
——, sp.	c.						
—— (Crioceras) Duvalii, *Léveillé*	...	C.	c.				
—— (Crioceras) Emericii, *Léveillé*	...	C.	c.				
——, sp	...	r.					
—— Puzosianum, *D'Orb.*	...	•••	c.				
—— (Hamites) raricostatum, *Phill.*	...	...	c.				
——, sp	...	...	...	...	...	c.	
Rostellaria Parkinsoni, *Phill.* (non *Sow.*)..	C.						
—— bicarinata, *Leym.*	C.						
Cerithium Clementinum, *D'Orb.* (var.)	r.						
—— Phillipsii ? *Leym.*	...	r.					
—— aculeatum, *Bean, MS.*	...	...	r.				
——, spec. nov.	...	r.					
Turritella lævigata, *Leym.*	r.						
Solarium (?) tabulatum, *Phill.*	r.						
Trochus (?) pulcherrimus, *Phill.* sp.	c.						
—— granulatus, *Bean, MS.*	C.						
——, spec. nov.	...	r.					
——, spec. nov.	...	...	r.				
Pleurotomaria provincialis, *D'Orb.*	...	...	r.				
——, spec. nov.	...	...	r.				
Auricula obsoleta, *Phill.*	c.						
Delphinula (?), sp., *Phill.*	r.						
Emarginula Neocomiensis, *D'Orb.*	R.						
Dentalium ellipticum ?, *Sow.* (casts)	r.						
—— lævigatum, *Bean, M.S.*	...	...	r.				
Ostrea Leymeriei, *D'Orb.*	R.						
—— frons, *Park.*	r.	r.					

Table showing the Vertical Distribution (continued).

	Upper Neocomian.	Middle Neocomian.	Lower Neocomian.	Portlandian.	Upper Kimmeridge.	Middle Kimmeridge.	Lower Kimmeridge.
Ostrea, sp.	...	...	r.				
——, sp.	...	...	...	...	...	r.	
Exogyra sinuata, *Sow.* (normal form)	c.	C.					
—— parvula, *Leym.*	r.						
——, spec. nov.	r.						
—— sinuata, *Sow.*, var. elongata, *Leym.*	...	c.					
—— Couloni (E. subsinuata, *Leym.*)							
—— ——, var. dorsata, *Leym*	...	...	C.				
—— ——, var. falciformis, *Goldf.*	...	...	C.				
—— ——, var. aquilina, *Leym.*	...	...	r.				
—— virgula, *Defr.*	...	•••	...	...	...	C.	
—— nana, *Sow.*	...	...	...	...	...	C.	
Placunopsis, sp.	r.						
Pecten elongatus, *Lam.*	c.						
—— orbicularis, *Sow.*	C.						
—— cinctus, *Sow.* (dwarfed var.)	r.						
—— cinctus, *Sow.* (normal form)	...	C.	R.				
—— interstriatus, *Leym.*	R.						
—— striato-punctatus, *Röm.*	R.						
Lima, spec. nov.	c.						
——, spec. nov.	c.						
—— undata, *Desh.*	r.						
—— elegans, *Duj.*	r.						
——, spec. nov.	...	r.					
Plicatula placunea, *Lam.*, var.	r.						
Avicula, spec. nov.	c.						
Gervillia anceps?, *Desh.*	r.						
Perna Mulleti, *Desh.*	c.						
Inoceramus venustulus, *Bean, MS.*	c.						
—— concentricus, *Sow.*? (small var.)	r.						
—— imbricatus, *Bean, M.S.*	r.						
Pinna gracilis, *Phill.*	r.						
—— granulata, *Sow.*	...	...	...	...	...	c.	
Modiola (bipartita, *Phill.* non *Sow.*)	...	...	...	...	...	r.	
Cucullæa securis, var. major, *Leym.*	r.						
Arca, spec. (casts)	...	...	...	c.			
Nucula obtusa, *Sow.*	C.	r.	r.				
—— ——, var. planata, *Desh.*	C.						
—— (Leda?) subrecurva, *Phill.* (N. scapha, *D' Orb.*)	c.	...	r.				
——, spec. (casts)	...	...	...	c.			
Leda, sp.	...	...	...	...	...	r.	
Corbis, sp.	r.						
Lucina sculpta, *Phill.*	...	R.					
—— crassa, *Sow.*	...	r.					
—— Portlandica, *Sow.*	...	...	...	C.			
Astarte lævis, *Phill.*	r.						
—— laticosta, *Desh.*	r.	r.	r.				
Isocardia anguiata, *Phill.*	C.						
—— (?), sp.	r.						
Trigonia spinosa, *Park.*	?						
Mya? phaseolina, *Phill.*	c.						

Table showing the Vertical Distribution (continued).

	Upper Neocomian.	Middle Neocomian.	Lower Neocomian.	Portlandian.	Upper Kimmeridge.	Middle Kimmeridge.	Lower Kimmeridge.
Thetis Sowerbyii, *Röm.* (var. major.)......	*r.*						
—— —— (var. minor)	*c.*						
Ceromya excentrica?, *Ag.*	...	...	...	...	...	*c.*	
Myacites, sp...............................	...	...	...	...	...	*c.*	
Panopæa plicata, *Sow*...	*c.*	?					
—— Neocomiensis, *Desh.* sp.	C.	*c.*	*r.*				
Thracia Phillipsii, *Röm.*?, var.	...	*c.*	*c.*				
—— —— ?, var.	C.						
—— depressa, *Sow.*	...	...	...	...	...	?	
Pholadomya Martini, *Forbes*	*c.*	*c.*					
——, sp.	*c.*						
——, sp.	*r.*	*r.*	*r.*				
——, sp.	...	...	...	...	...	*c.*	
Pholas constricta, *Phill.*	*c.*	...	*r.*				
Lithodomus, sp.	...	...	...	*c.*			
Teredo, sp.	*r.*	...	*r.*				
Serpula articulata, *Sow.*	*c.*	...	*r.*				
—— filiformis, *Sow*.......................	*c.*	*c.*					
—— antiquata, *Sow*.......................	*r.*	*c.*					
—— gastrochænoides, *Leym.*	...	*r.*					
Vermicularia Phillipsii, *Röm.* sp.	C.	*r.*					
—— —— (reversed var.)	R.						
Terebratula sella, *Sow*....................	*c.*	*r.*					
—— depressa, *Lam.*?	*r.*	*r.*	*r.*				
—— hippopus, *Röm.*	...	?					
Terebratulina striata, *Wahl.*, var. pentago-nalis, *Phil.*	R.						
Waldheimia celtica, *Morris*.................	...	*r.*					
Rhynchonella sulcata, *Park.*	*r.*	*r.*	*r.*				
—— lineolata, *Phil.* sp.	R.						
——, sp...............................	R.						
—— inconstans, *Sow.*	...	...	...	...	...	...	R.
——, sp...............................	...	...	...	...	...	*r.*	
Discina, spec. nov.	R.						
Discina latissima, *Sow.* sp.	...	...	...	...	C.		
Lingula truncata, *Sow*....................	*r.*						
—— ovalis, *Sow.*	...	...	...	...	C.		
Cidaris, sp.	*c.*						
Pseudodiadema, sp.	*c.*						
Toxaster complanatus, *Ag.*	?	...	R.				
Pentacrinus angulatus, *Röm.*	*c.*	*r.*					
——, sp.	*r.*	*r.*					
——, sp.	...	...	...	...	...	*r.*	
Trochocyathus conulus, *Phill.*?	*r.*						

Note.—Beside the fossils included in the above list, there is a considerable number of other species in the Speeton Clay, not a few of which appear to be altogether new to science. In the case of some of those given, future researches will doubtless show their ranges to be more extended than is indicated in the table.

Appendix B.—*Notes on the distribution of some of the Speeton-Clay Fossils.*

So great is the number of species belonging to the Speeton Clay, a large proportion of them being new, that I propose on the present occasion to notice only such facts with regard to their distribution as may be necessary for establishing and illustrating the conclusions at which I have arrived with regard to the age of the beds. The general examination and description of the fossils will be best undertaken in connexion with those of the Tealby series and the other Neocomian beds of this country, and will be more satisfactorily performed after a more extended comparison of them with the fossils of foreign Neocomian strata.

Nautilus.—All the species of this genus as yet known from Speeton have been obtained from the " Cement-beds." It is interesting to find that we have here the whole of the Lower-Greensand species, viz. *N. radiatus*, Sow. (*N. Neocomiensis*, D'Orb.), *N. plicatus*, Sow. (*N. Raquienianus*, D'Orb), and *N. pseudo-elegans*, D'Orb. These species also occur in the Upper Neocomian of France.

Belemnites.—Among the Belemnites of the Speeton Clay there are several well-marked species with limited vertical ranges, which afford considerable assistance in the classification of the beds.

B. semicanaliculatus (Blainv. ?)—This form is certainly identical with that found in the Lower Greensand ; but I have very strong doubts as to whether it is rightly referred to De Blainville's species. At Speeton it is very abundant in the Upper Neocomian, and scattered specimens occur in the Middle Neocomian.

B. jaculum, Phill.—This well-marked species has received a great number of names—among others, *B. minimus*, Sow. (pars), *B. fusiformis*, Y. & B. (pars), *B. subfusiformis*, Rasp., and *B. pistillum*, Röm. It is a very variable form, and has been split up by some French authors into a great number of species. At Speeton it is very characteristic of the Middle Neocomian, its metropolis being in the " Ancyloceras-beds." It also ranges downwards into the Speetonensis- and Noricus-beds, in the latter of which, however, it is extremely rare. The same species is also abundant in the Tealby series of Lincolnshire, in the Hilsthon, and in the Neocomian of France and Switzerland.

B. lateralis, Phill.—This species, which is the *B. subquadratus* of Römer, occurs in prodigious numbers in the zone of *Ammonites Astierianus*. In these beds it often reaches a gigantic size, some specimens being 8 inches long, and $1\frac{1}{2}$ inch in diameter. These large specimens are always remarkable for the eccentric mode of their growth, and were among the specimens figured and described by Young and Bird as *B. excentralis*. The smaller forms of this species occur, though but rarely, in the beds above the zone of *A. Astierianus*.

Ammonites.—Although the fossils of this group are found in considerable abundance in the Speeton Clay, their study is nevertheless attended with very considerable difficulties. In a large majority of instances the specimens occur mineralized by pyrites ; and in almost all these cases it is only the central portion of the shell which is

preserved. In a number of the species the adult forms are wholly unknown, while in others the young or fragmentary specimens have received different names from the adult or complete forms of the same species.

A. Deshayesii, Leym.—This Ammonite, which is a very variable one, is confined, I believe, to the upper division of the Speeton Clay, where it is by no means rare. It is the *A. fissicostatus* of Phillips, while the *A. curvinodus* of the same author is probably only one of the numerous varieties of it.

A. bipinnatus, Williamson, MS. This is a large and well-marked, though undescribed species. It characterizes the Middle Neocomian at Speeton, and is also abundant in the Tealby series of Lincolnshire.

A. Speetonensis, Y. & B.—This is the most abundant of the Speeton Ammonites. It includes the *A. venustus* and the *A. concinnus* of Phillips, as well as two other well-marked varieties, one a more inflated and coarser-ribbed form than *A. concinnus,* and the other more compressed and with finer ribs than *A. venustus.* All these forms pass into one another by insensible gradations; none of them occur, so far as I am aware, either above or below the Speetonensis-beds in the Yorkshire deposit. The same group of forms is found at Potton, and in the Lower Neocomian of South-eastern France.

A. Noricus, Schloth., Röm.—This is certainly the *A. Neocomiensis* of D'Orbigny. It is by no means a rare shell at Speeton, and received from the late Mr. Bean the MS. name of *A. regalis.* In the zone which is characterized by this species are a number of varieties of it, which were considered to be species, and received the MS. names of *A. munitus, A. furcillatus,* &c. When a sufficient number of specimens is examined, they are found to pass into the normal form of *A. Noricus* by insensible gradations. Several of D'Orbigny's Neocomian species of *Ammonites* are certainly only varieties of this species. The form with a broad smooth back, which is found at Speeton, and which is certainly the *A. consobrinus,* D'Orb. (*A. evalidus,* Bean, MS.), may also be only a variety of the same species.

A. Astierianus, D'Orb.—This is a most variable form. D'Orbigny figures two very dissimilar specimens as possibly male and female shells. There seems to be every gradation between the compressed form, *A. multiplicatus,* Röm. (very well marked specimens of which occur at Speeton), and the well-known highly inflated form. Although this species is most abundant in the beds which I have named after it, scattered specimens of it appear to occur higher in the series.

A. Nisus, D'Orb.—This is undoubtedly the *A. planus* of Phillips, though not of Mantell. Mantell's shell is only one of the numerous varieties of the Gault species *A. splendens.* The form referred to by Professor Phillips as "like *parvus*" is probably only the young of *A. Nisus.*

A. rotula, Sow.—This is the *A. Youngii* (Bean, MS.), Y. & B. I have obtained specimens reaching $3\frac{1}{2}$ inches in diameter, and also others which are intermediate in size, and which enable us to form

a complete series between the somewhat common young form and the rare adult. I have not yet been able to determine whether the form named *A. trisulcosus* by Phillips is really distinct. There can, however, be little doubt that several Ammonites described by D'Orbigny in his group of the *Ligati* are really only forms of the British species.

A. hystrix, Phill.—This is a very well-marked and beautiful species occurring in the Astierianus-beds, where, however, it appears to be very rare. D'Orbigny records it from the Lower Neocomian of South-eastern France. It is certainly quite distinct from the *A. Mantelli*, a Lower-chalk form.

A. marginatus, Phill., *A. nucleus*, Phill.—I was at one time inclined to consider these as the same species; but the examination of a large series of specimens in the Scarborough Museum shows that the former, even in its younger stages, has the tubercles around its umbilicus, of which the latter is destitute. They must therefore for the present be kept distinct; their adult forms are, so far as I am aware, altogether unknown. The species referred by Römer to *A. nucleus* is certainly quite distinct from the British form, and appears to belong to a Neocomian species not yet, I believe, found at Speeton.

Ammonites angulicostatus, D'Orb.—This very interesting species appears to form a connecting link between the genera *Ammonites* and *Ancyloceras*. In the young form the whorls are in contact, but with advancing age the outer whorl becomes slightly detached from the others. By Quenstedt this species was regarded as belonging to *Crioceras*. It is well figured and described by Pictet and De Loriol, 'Terrain Néocomien des Voirons' (Invertébrés), p. 23, plate 4.

Several other species of Ammonites, some of which appear to be new, also occur in the Neocomian beds at Speeton.

The various coronated forms of *Ammonites* which occur at Speeton, and were called by Mr. Bean *A. cavatus*, *A. quadrifidus*, &c., are certainly identical with certain continental Portlandian species, as already noticed by Mr. Leckenby. The cabinet of that gentleman contains the most splendid materials for their study. I cannot help thinking that they will all prove to be varieties of one species, though for the present I have kept them distinct, and called them by the names under which they are known on the continent.

Ancyloceras.—Great as are the difficulties attending the study of the Speeton Ammonites, they are light in comparison with those which meet us in working out the species of the genus *Ancyloceras*. In examining a large series of forms belonging to this group we are struck by their enormous powers of variation. Thus a specimen which has grown to a certain stage with simple ribs, and without any appearance of spines, will suddenly exhibit a most extraordinary development of those appendages; and in the same way a most strikingly spinous species will as suddenly become smooth. Now, in the large majority of instances, we find at Speeton small and detached fragments of a single whorl only, which for the purposes of identification and description are absolutely worthless, and which, if so made use of, can only be sources of error. For these reasons I think that

the various species of this group, founded by Young and Bird, Phillips and Römer, generally on the smallest fragments, might with no loss, but much positive advantage, to palæontology be suppressed.

M. Astier, who by long residence in the south-east of France (in the Neocomian beds of which district the forms we are considering attain their maximum of abundance and perfection of preservation) has had peculiar opportunities for studying the whole group, shows that in the great majority of instances, if not in every one, the species hitherto referred to the genus *Crioceras* really belong to *Ancyloceras*. The few Speeton specimens of this group approaching anything like a state of perfect preservation which I have been able to examine are certainly all referable to *Ancyloceras*, and I have as yet seen no specimen clearly belonging to *Hamites* or *Hamulina*.

With much diffidence, I would venture to indicate the following as among the species of *Ancyloceras* in the Neocomian of Speeton. In the Cement-bed occurs a form (*Hamites maximus* and *H. plicatilis*) which seems to belong to the same species as specimens grouped together by Professor Forbes under the name of *Scaphites grandis*. In the Middle Neocomian we appear to have undoubtedly the forms originally described by Léveillé as *Crioceras Duvalii* and *C. Emericii*, while lower in the series occur two other forms, *C. Puzosianum*, D'Orb., and a species near this, but probably distinct (*Hamites raricostatus* and *H. obliquecostatus*).

Ostreidæ.—*Ostrea Leymeriei*, Desh., has, so far as I yet know, been found only in the highest beds.

O. frons, Park., occurs in the Upper and Middle Neocomian at Speeton.

Exogyra sinuata, Sow., of the typical forms (*E. latissima*, Lam., and *E. elongata*, Leym.) occurs in tolerable abundance in the Upper and Middle Neocomian beds.

The zone of *Ammonites Astierianus* is exceedingly well marked by the abundance of the variety (subspecies of Leymerie) *E. Couloni*, or *E. subsinuata*; and all of the numerous varieties of this form described and figured by Leymerie and D'Orbigny may easily be collected at Speeton. The little form *E. parvula* of the former author, which also occurs at Speeton, is probably only the young of one of the others. A very well marked form, however, is the *E. subplicata* of Römer, which is confined at Speeton, so far as I am aware, to the Speetonensis-beds.

It is interesting to notice that many of these species and varieties were noticed in the Speeton Clay by Young and Bird. The typical form of *E. sinuata* appears in the 'Survey of the Yorkshire Coast' as *Ostrea carpax*, *O. frons* as *O. sinensis?*, and two of the forms of *E. Couloni* as *O. unguis* and *O. quadrata*.

Perna Mulletii, Desh.—This very interesting and highly characteristic species occurs in considerable abundance in the "Cement-beds," but has not, I believe, been found below that horizon.

Lima.—Several remarkably fine species of this genus, some of which are new, occur in the "Cement-beds" at Speeton. A beautiful new species of *Avicula* occurs likewise in these beds.

Myadæ.—*Panopæa plicata*, Sow., sp., and *P. Neocomiensis*, Desh., sp., both occur in the Speeton Clay, the latter being very abundant throughout the Neocomian beds.

Pholadomya Martini, Forbes.—Remarkably fine specimens of this shell occur both in the Upper and Middle Neocomian of Speeton.

Thracia Phillipsii, Röm., occurs in the Middle and Lower Neocomian, while a more elongated species or variety is found in the upper beds.

Thetis Sowerbyi, Röm.—Both the varieties of this shell, so abundant in, and characteristic of, the Lower Greensand, are found in the " Cement-beds " at Speeton.

Toxaster complanatus, Ag. sp.—Of this most highly characteristic Neocomian fossil the only known specimen from the Speeton Clay is in the Scarborough Museum. This fossil was identified by Agassiz himself in 1838. Its rarity, like that of all the more delicate fossils, is accounted for by the large quantity of easily decomposing pyrites which the lowest Neocomian beds at Speeton contain. This species, which is so very abundant in the Neocomian limestone, has received a great number of names, among which are *Holaster complanatus*, Ag., *Spatangus retusus*, Lam., *S. helveticus*, Defr., and *S. argillaceus*, Phill.

A *Cidaris*, with beautiful muricated spines like some of the French Neocomian forms, and a *Pseudodiadema*, with smooth spines, occur in the " Cement-beds " at Speeton.

Pentacrinus angulatus, Röm., and *P. Fittoni*? occur in the upper and the middle beds of the Speeton Neocomian.

Appendix C.—*On the Economic Products of the Speeton Clay.*

The Speeton Clay is not altogether without interest in a commercial point of view. For the last thirty years past the inhabitants of the neighbouring villages have been in the habit of digging at the surface of the cliff the large septaria of the " Cement-bed ;" these, as they were accumulated in sufficient quantities, were transported from time to time to Hull by coasting vessels. But during the last five or six years the cliff has been leased from the lord of the manor, and the " cement-stones " have been found so valuable as to induce the undertaking of regular mining-operations. The mode of working is as follows :—Timbered adits are driven into the cliff at points below the outcrop of the " Cement-bed ;" it has already been shown that the beds of the Speeton clay dip inland at a considerable angle, consequently these adits sooner or later meet the Cement-bed ; when this occurs, galleries are driven in every direction in the bed itself, the material and refuse being carried out in small waggons running on tramways which are laid down in the adits. The stone is now usually conveyed to Hull by railway.

The peculiar, light-coloured, fine-grained, argillaceous limestone of the Speeton septaria is manufactured into Roman cement, for which purpose it is very highly prized. The cement made from it is said to be particularly valuable, on account of the rapidity with which it sets and from its not being liable to crack in drying. In these

respects it is much superior to the cement made from the Lias nodules obtained at Whitby. Upwards of 1000 tons of the septaria are annually sent from Speeton to Hull.

The light-coloured, very tenacious clay in which the "cement-stones" are imbedded produces a very fine quality of Portland cement; but very little of it is at present exported, on account of the cost of carriage.

The "Coprolite-bed" at Speeton was first discovered on the shore, when the sand and shingle had been removed by a storm, and after-wards traced up into the cliff. It is now worked by adits in pre-cisely the same way as the "Cement-bed;" but, as it only averages five inches in thickness, this expensive mode of working is found to be scarcely remunerative, and is likely to be soon abandoned. About 500 tons of the "Coprolites" are annually exported from Speeton Cliff. They consist of very dark-coloured, almost black stone, con-taining much pyrites, and mingled with worn casts of shells. Samples tolerably free from the investing clay yield from 57 to 61 per cent. of phosphates.

Inland several of the beds of the Speeton Clay are worked for brick-making.

For most of these particulars I am indebted to Mr. E. Hunter, the present lessee of Speeton Cliff, who has kindly furnished me with a number of details, with permission to make any use of them I might see fit.

There now only remains the pleasing duty of expressing my obligations to the gentlemen who have assisted me in this investi-gation. To Mr. Etheridge, who has devoted much time to a tho-rough revision of my lists of species, I am particularly indebted, as well as to Mr. Davidson, who has furnished me with some valuable notes on the Brachiopoda. To Mr. Leckenby, of Scarborough, my thanks are especially due, not only for the use of his magnificent collection, but for the communication of many facts which the cir-cumstance of his being a resident in the neighbourhood had given him peculiar opportunities of accumulating. Lastly, to the Curators of the various Yorkshire and other museums, and particularly to Mr. Henry Woodward, of the British Museum, I desire to express my acknowledgments for the facilities they have always so readily granted to me for studying the collections under their care.

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2. *Notice of the* HESSLE DRIFT, *as it appeared in* SECTIONS *above* FORTY YEARS *since*. By JOHN PHILLIPS, Esq., M.A., D.C.L., F.R.S., F.G.S., Professor of Geology in the University of Oxford.

THE progress of modern research has brought before us, on a great scale and under various aspects, a subject which, until the series of strata began to be studied by W. Smith, had literally no place in British geology. By that observer, first of all men, the "superficial deposits," as they were called, were separated from the "regular strata," and referred to a different and more tumultuous origin.

Dr. Buckland popularized this idea, and, under the title of "diluvial" deposits, presented a great number of important observations relating to the final operations on our land of the waters of the sea, followed by river-floods and ordinary atmospheric action*.

Modern research has convinced us that, instead of that diluvial accumulation being the work of one transitory and confused disturbance of the level of sea and land, there were successions of drifted deposits, under different conditions, having unequal distributions, and peculiar local directions. We have not merely translated the antique "diluvial" into the modern "drift;" the abnormal cataclysm has become an intelligible series of local sea-actions and limited displacements of land; the crisis has become a period: Preglacial and Postglacial eras are marked in time, and characterized by successive races of animal and vegetable residents.

Those who, like myself, had to struggle with the Boulder-clays and northern drift more than forty years ago, without the aid of glaciers and icebergs, and with no clear theory of the changes of level of land or sea, were apt to leave out of our local descriptions phenomena which seemed merely perplexing, or merely exceptional. Yet we attempted, even then, to express some ideas of the succession among diluvial beds; and we now recognize in the full descriptions of the cliffs of Yorkshire and Norfolk the facts which we had seen as clearly, but had not been able to enunciate in language suited to their importance, or conformable to modern theory.

In the notices which have been presented to the Geological Society of late years touching the drift-deposits of the South Yorkshire coasts, reference is usually made to a description which I gave in 1829, and repeated in 1836, of some shell-bearing gravels near Ridgemont†, and some ossiferous gravels and Boulder-clays at Hessle‡. But these descriptions were too brief to give a sufficient idea of what was observed; so that in the former case it does not seem to have occurred to the authors referred to that the shelly gravels were regarded by me as lying *in the Boulder-clay series*, and were described in this relation by reference to Dimlington, Skipsea, Brandsburton, and Paghill. In regard to the Hessle deposit, it seems desirable to present the original observations, made in April 1826, because, as I am informed, the sections now to be seen in the pits are neither so clear nor so extensive as they were when I first examined them.

These sections and descriptions are given without any change.

"12 April 1826.

"Walked to Hessle, &c. The gravel lies over chalk and flint, itself composed of such fragments.

"(a) Thick bed of brown and blue clay, with chalk, &c. At No. 3, further on, it contains coal, chalk, flints, granites, gneiss, syenite, limestone (red and blue), porphyry, hornstone; and I found what seemed an elephant's tusk.

* Reliquiæ Diluvianæ, 1823.
† Geol. of Yorkshire, vol. i. ed. i. p. 52, ed. ii. p. 23.
‡ Ibid. ed. ii. p. 20.

"(b) The same (smaller) gravel, in thin layers, alternating with pretty thick bands of silt (a finer deposit), which are regular here, and look like the recent marine and fluviatile deposits, but at (2) are curved, so as to look like diluvial action, likewise there less regular and not so abundant.

Fig. 1.

1. Warp.   2. Pebbles.
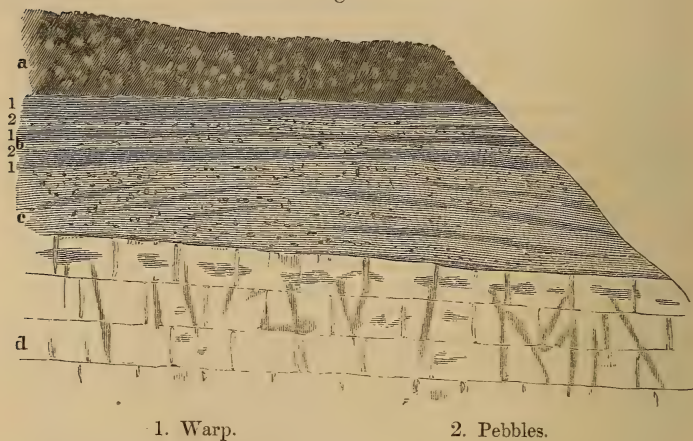
Fig. 2.
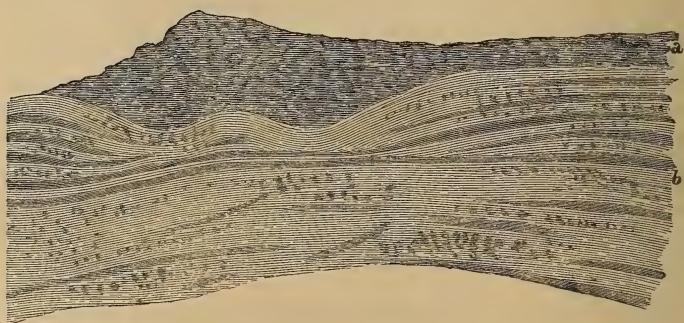
"(c) Gravel, chiefly of chalk and flint, in small fragments, a few marks of coal, some pieces of shelly lias; bones of horse, the teeth and metatarsals sound, other bones rotten.

"(d) Chalk, at bottom solid, with large flints at and near the top."

In my researches on the diluvium of the Yorkshire coast (1829), I expressly rejected, as entirely without foundation, the supposition which had then some currency, that the forest-remains in the Holderness district were "antediluvial," like some of the forest-beds on

Fig. 3.
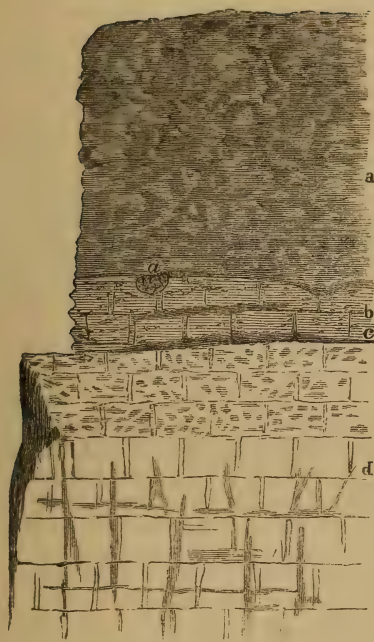
a. Granite block.

Fig. 4.—Sketch-section of Hessle Cliff.
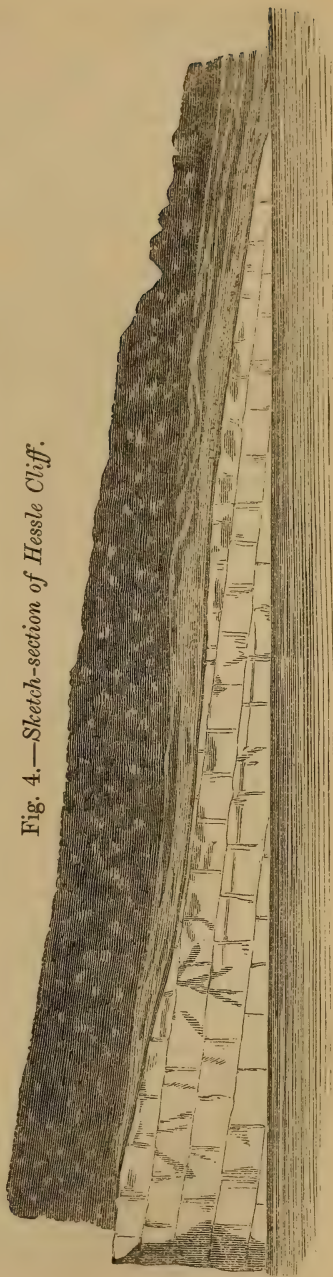
the Norfolk coast.   But in regard to the lowest Hessle gravels, which rest upon chalk and are covered by Boulder-clay, I had always a different opinion ; and when, in 1853*, I published a classification of Yorkshire deposits, in which the terms Preglacial, Glacial, and Postglacial were employed, these gravels, as well as the contents of Kirkdale Cave, were counted by me as of *Preglacial* date, while the Bridlington Crag was regarded as only a little later than the Upper Crag of Norfolk.

Now all this is changed; the cavern-mammalia are regarded as *Postglacial*, the Hessle clay becomes an upper Boulder-clay, and the Bridlington Crag is treated as a part of the same great series of drift deposits, after suffering divorce from its partner in Norfolk.

While these questions are still *sub judice,* fresh evidence may be admissible.   I have something to offer on each of them, but at present limit my remarks to the Hessle section of Boulder-clay, gravelly drifts, and chalk.

The Hessle clay, if it be the upper part of the great Holderness deposit, and not met with beyond the outcrop of the chalk, must be designated as a third Boulder-clay ; for everywhere north of the promontory of Flamborough—at Speeton, Filey, Scarborough, and Whitby—the Boulder-clay is in two layers, separated by gravels and sands, or sands only, water not unfrequently coming out of the intermediate layer.   It is quite possible that this series of clays may really be triple ; it is certainly double at several points, both north and south of Flamborough Head.

The clays, full of fragments of various rocks, which appear north of Flamborough Head, were certainly deposited on a previously waterworn surface.   The level vale of Pickering, partly formed upon a surface of Boulder-clay, may be regarded as a large Preglacial vale, or sea-loch, which became blocked during the Glacial depression by drift at its eastern end.   Through this drift short streams have since cut their way to the sea, to which, in earlier times, the Derwent had probably flowed by a short and rapid course, accompanied, most likely, by the Seven, Rye, and other western waters, which now descend to the Humber through the gorge at Malton.

In like manner Scalby Beck, north of Scarborough, runs in a channel which it has cut through drift, which drift lies in an older and broader valley, cut into the sandstones and shales in Preglacial times. Just such phenomena appear in the broken cliffs and road-cuttings between Whitby and Sandsend : a broad old hollow of Upper Lias has been heaped full of northern drift, through which, at a later time, the small streams have won their uneven way to the sea.

On the surface of the subjacent rocks, under the drift, there is to be seen, at a few places, a peculiar rubble, composed mostly of portions of these rocks, much like what is occasionally seen at the surface of strata which have been exposed to disintegration by atmospheric agency, and, like that, occasionally displaced (Filey Brig).

By observations of the same kind at Dane's Dyke and other chalk valleys filled with drift south of Flamborough Head, the same pro-

* Rivers, Mountains, and Sea-Coast of Yorkshire, 1853.

position is supported, viz. that in diluvial soils, and even " in solid strata, small valleys have been excavated by the streams which run in them, or else by postdiluvial floods" * ; while often below them, and below the drift in which they are found, Preglacial valleys of greater amplitude occur, whose now subterranean surface is covered by gravel, sand, and conglomerate, distributed as if by atmospheric agency before the expansion of the Glacial sea.

Turning now to the sections of Hessle cliff, we see, upon the wasted surface of the chalk, accumulations similar to those just mentioned on the chalk cliffs north of Bridlington. They appear to me to be of the same geological age, and I have regarded the elephants and horses which they contained as of Preglacial date.

I am disposed still to favour this opinion ; for though the removal of the Hessle clay to a higher place in the series than was assigned to it deprives me of one support to my argument, there are still grounds to be relied on. In the first place, there is no proof that these beds are marine, but a strong presumption to the contrary, from the considerable abundance of land mammalia found in them, especially *Elephas primigenius* and horse. And, secondly, beds of this order, composed of chalk and flint fragments, not only are not known to occur in the midst of the Boulder-clay, but can hardly be imagined to exist there. And, thirdly, the Boulder-clay rests on them without conformity.

FEBRUARY 5, 1868.

Arthur Humphrys Foord, Esq., 12 Woodland Terrace, Blackheath; Rev. Robert Hunter, M.A., 9 Mecklenburgh Street, W.C.; Frederick Newman, Esq., Civil Engineer, 51 Belsize Road, St. John's Wood; and Hugh Seymour Tremenheere, Esq., Tremenheere, Cornwall, were elected Fellows.

The following communication was read :—

1. *On the* PHYSICAL GEOGRAPHY *of* ARGYLLSHIRE *in connexion with its* GEOLOGICAL STRUCTURE. By His Grace the DUKE OF ARGYLL, K.T., F.R.S., F.G.S.

IN a work published in 1865 upon " The Scenery of Scotland viewed in connexion with its Physical Geology," Mr. Geikie has set forth with much ability certain theories upon that subject which seem to be gaining ground with the younger school of geologists.

Not believing in the truth of those theories, I have selected the work referred to as the best text I could find for the purpose of bringing them under discussion. Although a popular treatise, the work of Mr. Geikie is at once elaborate and systematic. It states the questions in dispute with great distinctness. I propose therefore in this paper to deal with the theory of the " Erosionists " as I find it there defined and there defended.

According to these theories subterranean movements and commo-

* Geol. of Yorkshire, vol. i. ed. i. p. 71, ed. ii. p. 43.

tions have had comparatively very little to do with the origin of the hills and valleys of the Highlands. Their form is mainly due to atmospheric powers of waste acting slowly and gradually through uncounted "millions of years." The mountains have been carved out of the original thickness of the strata of which they are composed. The valleys are nothing but the hollows out of which vast masses of material have been removed; and, further, this removal has not been effected by convulsions of any kind, but merely by the streams which now occupy the bottom of the glens, and, during the Glacial period, by continuous masses of ice which passed downwards from a few central ridges to the sea. This theory is stated and restated in many forms, with some variety as to the amount of allowance made for subterranean movements, but always with a careful limitation of that allowance to just so much of it as will help the favourite theory, and will not embarrass it. I quote one of these forms of statement that we may have the theory before us in the author's words, "The conclusion, therefore, to which an attentive examination of the present surface of the country points, is that although the rocks have unquestionably suffered much from subterranean commotions, it is not to that cause that the present external forms are chiefly to be traced; that the mountains exist, not because they have been upreared as such above the valleys, but because their flanks having been deeply cut away, they have been left standing out in relief; and that the valleys are there not by virtue of old rents and subsidences, but because moving water, with its helpmates frost and ice, has carved them out of the solid rock."

Now, as regards at least that large area of the West Highlands which is included in the county of Argyll and its adjacent islands, my belief is precisely the reverse of the theory here stated—that although the atmospheric agencies of waste have produced great modifications of the surface, the form of the hills and valleys has in the main been determined by the action of subterranean forces, that the mountains have not been cut or carved out of the thickness of some ancient tableland, but have mainly arisen from upheavals and subsidences, and lateral pressures, which have folded them and broken them into their present shapes—that the work done by rivers in excavating their own course has been comparatively small, that they have not cut out for themselves the valleys in which they flow, but have taken channels determined for them by movements from beneath.

In conducting this argument, then, let us look in the first place for such facts as are admitted on both sides, and, if there be any, for such principles applicable to those facts as are not capable of dispute. In this case it is satisfactory to find that both in respect to fact and to principle there is at least some common ground to start from.

First, there is the fact that the mountains of the Highlands are composed for the most part of strata which are not horizontal, but inclined at every variety of angle. This cannot be stated in language more expressive than that employed by Mr. Geikie himself. He says " The strata of sand and mud, accumulated to a depth of thousands of

feet over the sinking floor of the old Silurian Ocean, have been crumpled up into endless folds and puckerings, of which, as may be seen on the map, the long axis, or ‘ strike,’ runs generally in a north-easterly and south-westerly direction.   When the wind blows from the N.W. the sea is roughened with long broken lines of wave stretching from S.W. to N.E. and rolling in towards the S.E. ; so, over the Scottish Highlands, the gneissose and schistose rocks have been tossed, as it were, by a long swell from the N.W. into numerous wave-like plications that follow each other, fold after fold, and curve after curve, from Cape Wrath to the Lowland border.”

Let us now consider for a moment what is involved in this fact. Those “ waves,” those “ foldings,” those “ puckerings,” those crumplings of the strata are due of course to subterranean force.   When those forces were in operation, when the movements due to them took place, these movements must have been transmitted to the then surface of the ground.   It matters not what that surface may have been, nor whether it was dry land or a sea-bottom.   If the beds when suffering dislocation were themselves at or near the surface, then of course that surface would directly represent and reproduce the subterranean movement.   If they were not near the surface, but covered at the time by other rocks, still those rocks must have partaken more or less of the dislocations which were going on below. It is impossible that superincumbent strata should have maintained an undisturbed position when the lower rocks on which they rested were being “ crumpled ” and “ puckered,” and tossed into waves which can only be likened to waves of the sea.   In either case, therefore, the then existing surface of the earth over the whole area under which these movements prevailed must have had its shape and contour powerfully affected by them.

Now let us advance a step further.   Two suppositions are possible as regards the position of the surface which must have been so affected.   It may have been a surface already raised into dry land, or it may have been a surface wholly lying beneath the waters of the ocean.   In the case of its having been dry land, the old lines of drainage would necessarily be changed by the changed inclinations of the ground.

These would determine anew the course of streams and all the other atmospheric agencies of erosion.   It matters not whether the contortions of the underlying strata were slow or comparatively sudden.   The overlying surface must follow the movements of its support ; and however modified by materials bearing different degrees of tension, there must have been established from time to time a general conformability between the “ crumples,” the “ waves ” below and the hollows and the heights above.   Again, let us take the other case.   Let us suppose that the whole surface affected was beneath the ocean when its underlying support began to be tossed and crumpled.   It is in the highest degree improbable that subterranean movements so extensive should not have been accompanied by some changes in the distribution of land and sea.   Supposing the disturbed strata to have been wholly under water when the movement

began, it is in the highest degree improbable that they all re-
mained under water by the time it ended. Even, therefore, in
the case supposed, it is probable that the same movement which
rolled and crumpled the strata, elevated at the same time into dry
land great portions of the bed of the sea. The form, again, in
which that sea-bed rose above the waves would be determined by
the lines of subterranean elevation, and along those lines the new
agencies of atmospheric denudation would be compelled to act. The
theorist, therefore, who maintains that movements of such tremendous
power as those which are admitted to have tossed the strata of the
Highland mountains, have nevertheless had but a subordinate part
in determining the existing physical geography of the country, can
have only one other hypothesis to suggest. He must suppose that
the strata of the Highlands, after all the tossing and crumpling, and
the movements affecting them were ended, still remained, or were
subsequently again submerged under the sea, and that thousands of
feet of new beds were laid down unconformably upon them, filling
in all their folds, and covering up all their crests. He must further
suppose that these more recent deposits were again raised by some
new movement coming from a different quarter, and along different
lines of elevation. Then, indeed, these new lines of elevation would
be also the new lines of drainage, and the heights and hollows of the
new country might have little or no reference to the old " tossings "
which lay buried underneath.

This accordingly is the theory which Mr. Geikie adopts in some
passages of his work, although it is wholly inconsistent with facts
which in other passages he himself admits. He states broadly that
little or nothing of the surface which we now see is due to the
squeezing, crumpling, and breaking to which the strata have been
subjected. He says :—" These changes went on beneath the surface
under a vast thickness of rock which has since been worn away.
There is now no trace of the original effects produced by these un-
derground movements upon the exterior of the earth's ' crust.' If
they ever made any show there at all (which seems to me by no
means certain), they have been effaced long ago."

To estimate the boldness of this assertion we have only to follow
the hypotheses it involves, and then to compare these hypotheses
with admitted facts relative to the structure of the country. Let it
be conceded that the contorted strata which now constitute the
mountains of Argyllshire were once covered by a great superincum-
bent mass of Old Red Sandstone. Let it be conceded also that this
superincumbent mass was wholly unconformable to the convoluted
rocks beneath, and that when raised into dry land it presented a
surface whose outlines had no reference to the old folded schists.
In this case it is of course quite possible to suppose that lines of de-
pression in this Old-Red-Sandstone country might correspond with
lines of elevation in the more ancient rocks below, or might cut
across them at every variety of angle and inclination. Now let
us trace out what must have happened in some such instance. Let
us suppose the Old-Red-Sandstone depression running along a line

which was a line of ridge and of elevation in the older rocks.   The
streams of water, or of ice, or of both, which would follow in that
depression, would be so guided in their work that the valley would
be cut deeper and deeper, until at last, according to Mr. Geikie's
theory of erosion, after millions of years, the cutting would reach
the slaty rock which originally had been thousands of feet under-
ground.   That rock, at the point so reached, might be (as regards its
own geological structure) not a depression but an elevated ridge.
The crown of that ridge would then begin to be cut away, provided
the containing walls of the Old Red Sandstone valley continued
during further ages to guide and constrain the stream in the same
line of cutting.   We must now suppose that this guidance continued
so long that the underlying slates have been carved and exca-
vated into a deep glen.   We should then have a glen excavated along
the top and out of the anticlinal ridge of an old Silurian hill; what
had once been the bowels of a mountain would thus be one of the
containing sides of a valley.   And so over the whole area of the
Highlands we can suppose that, through the means and interven-
tion of an overlying country of sandstone, the underlying beds of
slate came to be cut and carved along lines which had not the
smallest reference to their own foldings and convolutions.   This is an
ingenious hypothesis, but it displays only half the ingenuity required.
Having called the Old-Red-Sandstone country into existence for the
purpose of the hypotheses, we must for the same sake get rid of it
again.   And not only must we get rid of it, but we must get rid of
it in a very peculiar manner.   If it were destroyed by the help of
new upheavals from below, these new upheavals would establish
new lines of drainage through the whole thickness of the strata they
affected, including both the sandstones above and the slates below:
and this new system of drainage could not but entirely alter the
former system, which had been constructed when the strata were at
rest.   That new system would come to be in general conformity
with the new geological structure given by the last upheaval.   But
this would never do: what we have to account for, according to the
theory, is a country showing no trace of original effects produced by
underground movements.   We must therefore get rid of the whole
sandstone country without any serious disturbance.   It must be done
very gently, by nothing more violent than what Shakespeare calls
" the gentle rain from heaven;" and yet it must be done so com-
pletely that over the whole area of the central Highlands not a frag-
ment, not a pebble, of this great sandstone country shall be left
behind.   And if for this purpose it be desirable to call in the agency
of the sea, then we must suppose that the country was just dipped
under the ocean, so slowly and so gradually that when every morsel
of the sandstones shall have been washed away, the old slates may
again be lifted as slowly into the air with the river-system unbroken
and untouched, which had been due, *not* to its own structure but to
the structure of other rocks now removed.   In this way, and, so far as
I see, in no other way, could we account for a country with folded
and contorted strata, and nevertheless with a system of hill-valleys

showing no trace of the original subterranean movements to which those contortions are due.

In straining our eyes through the darkness of past time to imagine, as best we can, the methods of operation through which nature has attained the results which we now see, compulsion is laid upon us to entertain many new and strange conceptions of the things which have been done by Time and Force. Gradually, however, we become accustomed to a new order of ideas; and no theory need really startle us which complies with these two conditions :—first, that it shall ascribe to known causes nothing but known effects; and, secondly, that the combination of causes which it assumes shall be required for the explanation of facts which are thoroughly established and ascertained. But having more than enough to do to explain those facts of nature which are of this undoubted character, it is indeed a waste of ingenuity when we construct elaborate theories to account for facts which either do not exist at all, or exist only in a very different connexion from that in which we have by assumption placed them. The facts assumed by the theory are in my opinion to a large extent as purely hypothetical as the ingenious explanations which are invented to account for them. In support of this opinion I shall have to adduce in some detail independent evidence derived from that portion of the Highlands with which I am best acquainted. But in the meantime I may point out admissions involved in our author's own words, which seem to me to carry us a long way towards conclusions opposed to his.

We have seen that, when describing the foldings of the Highland strata, he compared them to those waves of the sea which are driven by a fresh gale from the north-west, and that he pointed to the map of the country as indicating by its leading lines the respective directions in which the longer and shorter axes of these waves have run. This of itself is a strange admission to be made by an author who proceeds to assure us in a later page that, "if subterranean movements ever made any show at all upon the surface, they have been effaced long ago" (!). But the fact thus admitted is too remarkable and significant to be passed over merely as illustrating the general truth of a poetical comparison. Look at the map of the north-west coast of Scotland. Nothing can be more striking than the general prevalence of lines having a N.E. and S.W. direction. It is not merely the great valley of the Caledonian canal with its chain of lakes running, as that valley does, across the whole breadth of the island, but it is also the general direction, with only an average deviation, of many of the great sealochs and of some of the great freshwater lakes of the Highlands. No geologist, even one who had never seen the country, could look on that map without being certain at a glance that there must be a geological cause for such a general prevalence of direction, and that the lines of physical geography were also in some way lines determined by lines of geological structure. Accordingly Mr. Geikie is himself compelled to admit that with reference to these "longitudinal" valleys, the agencies of erosion have been guided in their work by the prevailing strike of the strata, which strike, as he also admits, is

" followed along the same line by the larger faults, and by the anti-
clinal and synclinal axes." Geological structure, then, we have it
admitted, has determined the direction and the general parallelism
of all the longitudinal valleys of the Highlands, which may be roughly
stated at about one-half of the whole. It is true that nothing but
the general trend and direction of these valleys seems to be attri-
buted to geological structure. Strata of different degrees of hard-
ness are supposed to have been exposed along the line of strike to
the agencies of waste. These would cut away the softer strata more
rapidly than the harder, and, being once determined in a particular
direction, have gradually widened their channels, at first mere narrow
cuttings, into deep glens and valleys. But again it is further admitted
that the great faults of the country lie along the same line, as like-
wise the synclinal and anticlinal axes. These of course are due, and
due solely, to subterranean movements ; and so far as they are
coincident with the ridges and hollows of the longitudinal system,
they establish the lasting effects of such movements upon the existing
surface of the country.

How far, then, can this coincidence be traced ? Here I regret to
say I must part company with Mr. Geikie even in his account of
facts. He says broadly, in the first chapter of his work, that " For
one valley which runs along the line of a dislocation there are, I
dare say, fifty or a hundred which do not." And in a note on the
same page he adds emphatically that there is no point which the
detailed investigations of the Geological Survey have made clearer
than this. I feel all the boldness of contradicting one who is not
only an eminent geologist, but who has so long been specially engaged
as a geological surveyor. But as regards the valley-system of the
county of Argyll, I do venture to state my conviction that this
assertion is erroneous. And I am glad to observe that in a subse-
quent page of his work Mr. Geikie says that, " until the Highland
tracts are surveyed in minute detail, it will not be possible to ascer-
tain how far they are traversed by lines of fault, nor to what extent
such features have shown themselves at the surface and have served
to guide the excavation of the valleys."

As regards the Lowlands over which the survey has been carried,
the result seems to have effected some modification of the confidence
with which the Erosion Theory is asserted. Our author says, " after
a long and detailed examination of the contorted rocks of the Silurian
uplands *of the Southern counties*, I have been led to believe that the
faults and folds of the strata have *on the whole* only a secondary
influence in originating the present irregularities of the surface.
And this is *probably* the case also with the contorted and metamor-
phosed Silurian rocks of the Highlands." So far as this passage
involves an argument, it does not seem a very good one. The
Highlands, as compared with the Lowlands, are what their descriptive
name implies them to be. They are lines of special upheaval and
subsidence and contortion ; and it is NOT probable, but in the highest
degree improbable, that an area of country under which subterranean
movements have been so much more marked than elsewhere should

not have had its surface affected by them in a correspondingly predominant degree.   Even as regards the Lowlands, I am suspicious, I confess, as to the influence which a preconceived theory has had on the estimate of evidence which appears to be so nicely balanced. But in any case the argument from analogy, as between the Lowlands and the Highlands, is one on which no reliance can be placed.

I have quoted in a former page the general description, given by Mr. Geikie, of the Highland strata, as waved and crumpled and tossed into wave-like plications or folds : and in another passage, speaking not especially of the Highlands, but generally of the Earth's crust, he says that "there is no dispute regarding the abundance of the upheavals, subsidences, and dislocations which it has undergone." But these general admissions are but a poor compensation for the silence which Mr. Geikie maintains on a whole class of the most important facts connected with the structure of the country.   It would have been more satisfactory if he had included in his descriptions some notice of the appearances of subsidence and dislocation which are to be observed in that particular part of the Earth's crust which constitutes the West Highlands, and especially if he had given us some account of the relation in which the dislocated sedimentary rocks stand to masses of granite or of other apparently intrusive rocks.   But this is a subject, surely one of the most important of all, on which we derive no information whatever from Mr. Geikie's volume.   There is, indeed, a passage in which he asserts that the convolutions of the old crystalline rocks " cannot be assigned to grand primeval eruptions of Granite."   The reason which he assigns for this assertion is, that although granite rises up among the highest mountain groups, " it also occupies wide spaces of low ground," a fact which, so far as I can see, has no bearing whatever on the question.   Mr. Geikie then throws off in a single passing sentence a theory as to the origin of granite, which he produces no facts whatever to justify, and which, again, even if it were true, would in no way decide the question how far the manner in which the contorted sedimentary strata are associated with Granitic rocks does, or does not, indicate the predominant effect of subterranean movements on the present physical geography of the country. " Indeed," says Mr. Geikie (and this is the sentence to which I refer), " *there is good reason to believe that granite is not an igneous rock in the ordinary sense, but that, instead of bursting through and upheaving the Gneiss and Schist, it is itself only a further stage of the metamorphism of those rocks.*"   What Mr. Geikie means by " igneous in *the ordinary sense of the word*," can only be conjectured.   If he means that granite is not " igneous " in the same sense in which trap is igneous, I quite agree with him ; but then I thought this is now pretty generally accepted and understood.   It has, however, nothing whatever to do with the question before us.   It may also be true that granite is composed of materials originally derived from sedimentary rocks, and that it represents only a further stage of metamorphic action.   But neither would this proposition, even if it were established, which it certainly is not, in the slightest degree affect

the question whether granite is not a case of metamorphism carried
to the extent of fusion ; nor can it release any geologist who theorizes
on a purely mechanical problem from the obligation of reconciling
his theory with the observed relations which exist between those
rocks which retain all the marks of their sedimentary origin and the
granites which, if they ever had that structure, have entirely lost it.

It is all the more remarkable that Mr. Geikie should have
bestowed so little attention upon this point, since his own general
description of the Highlands might have indicated to him the
immense significance of any facts bearing on the mutual relations
of the granites and the slates.   His general description is, that the
strata of the Highlands resemble the waves of a sea driven before a
N.W. wind.   Surely it must occur to every one to ask what was the
condition of the strata when they were subject to this subterranean
wave-like movement.   Were they already consolidated into hardened
rock, or were they still in the condition of original deposit,—soft
beds of sand and mud ?   Even in this last case, such movements
would in all probability be accompanied by slips or breakages at
right angles to the line of motion.   Even water when moved in
waves will break at the top, when the line of elevation reaches a
certain angle.   But if the Silurian strata of the Highlands had
already been consolidated into hard and even crystalline rock when
this wave-like movement was propelled along them, it is incon-
ceivable that it should not have occasioned fractures and dislocations
and subsidences of the strata, according to the different degrees of
tension which the different beds might be able to bear.   Nor is it
less certain that, along these lines of fracture and subsidence, what-
ever subterranean matter there might be in a fluid or in a viscid
state would find its way to the surface by splashing or protrusion
along the lines of least resistance.   And yet the geologist who tells
us that the crystalline rocks of the Highlands have been actually
puckered and crumpled and contorted by subterranean force, never
seems to think it worth his while to inquire what evidence on these
points is afforded by the structure of the country—whether granites
do or do not appear along the lines of fault or of upheavals or subsi-
dences of the surface, or whether any facts exist to show the
mineral character of the disturbed strata at the time when the
fractures were effected.   The theory assumes that the country first
rose out of the water like some great rounded mud-bank, sloping
gently from its summit to the sea, and that along those slopes
it was gradually cut and carved into hill and valley by the exca-
vating power of mere natural drainage. Mr. Geikie admits, indeed, that
" *perhaps* the elevatory force showed itself in the upheaval of one or
more anticlinal folds."   But, as usual, admissions which, if followed
up into their legitimate consequences, would powerfully affect the
argument, are practically set aside almost as soon as made.   Our
author's favourite illustration of the method in which the river-
system of the Highlands was established, is the mode in which a
miniature system of streams is made in a bed of wet sand which
has been left by the tide.   That is to say, the mechanical effect of

rain, falling on rocks already hardened and contorted, is compared with the action of water draining out of a material perfectly loose, saturated with moisture, and destitute of any guiding structure. For my own part I think this illustration enough of itself to upset the theory. I should say that the mechanical process which makes little rivers in wet sand from water welling out of its very substance, or coming with greater force from higher elevations, cannot possibly be the same which, under any conceivable conditions, cut the valleys of the Highlands out of the hard crystalline rocks of which the mountains are composed.

I pass, however, from these general considerations, which are useful only as showing the antecedent improbabilities involved in the extreme theories of erosion. I proceed now to test them on the field of fact; and I take, in the first place, that district of Argyllshire which lies between the northern banks of Loch Awe and the Frith of Clyde.

This is a district from which Mr. Geikie takes several of his illustrations. It is one with which I am well acquainted in detail; and it is one including within itself a grand display of all the characteristic phenomena for which it is necessary to account. I venture to assert, in opposition to Mr. Geikie, that almost the whole valley-system of this district, including both the longitudinal and the transverse valleys, is best accounted for by faults, by foldings, by subsidences, and by anticlinals among the strata.

To begin with—Loch Fyne itself, which is one of the main features of the country, and is well known to be one of the most prominent examples of that longitudinal valley-system which is so marked upon the map of Scotland, occupies, as I believe, the bed of an

Fig. 1.—*Section across the bed of Loch Awe.*
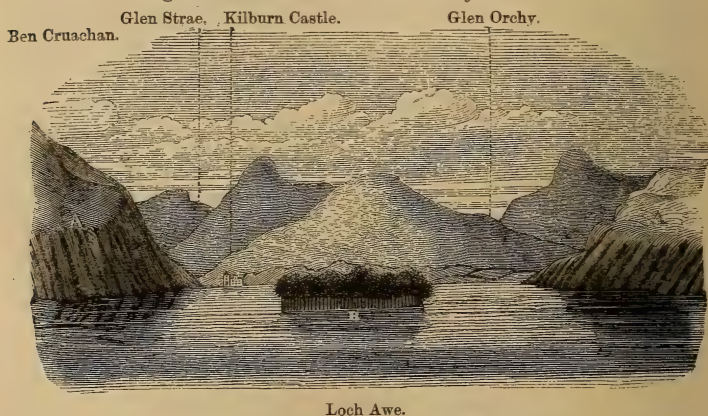
Loch Awe.
A. Slates on the opposite sides of Loch Awe.
B. Vertical slates on the Island of Freuchlin.

immense fault. Loch Awe, another of the valleys which assume the same general direction, lies along the line of a great subsidence or falling inwards of the metamorphic slates, and occupies the bed of

a great synclinal trough. The pass of the Awe, which Mr. Geikie quotes as an example of mere excavation, one of the most striking bits of scenery in the Highlands, through which the waters of Loch Awe find their way to the sea, is a rupture and chasm in the same rocks, connected with the subterranean causes which upheaved the great mass of Ben Cruachan to an elevation of 3600 feet. Glen Fyne is a continuation of the same line of fault which constitutes the sea-loch. The transverse valley of Loch Eck, connecting Loch Fyne with the valley of the Clyde, which also Mr. Geikie assumes to be a valley of erosion, lies across a steep anticlinal, and is due, in my opinion, to the extreme tension to which the crystalline rocks have been subjected along different lines of subsidence and upheaval. Loch Long and Loch Goil are due to similar causes. Glen Croe and Glen Kinglas lie in crumples of the strata, with every mark which could tell to the eye and to the reason of breakage, rupture, and dislocation. Many even of the smaller ravines which furrow the sides of the mountains, are not channels cut, but cracks occupied, by the torrents which now rush along their beds. Instead of becoming broader and wider as they descend, they are often chasms at the top of the mountains, and mere superficial channels below. The little niches which water has succeeded in cutting, during all the ages which have elapsed since the mountains became mountains, are sometimes perfectly distinguishable from the rents which subterranean force has opened to their course.

I have thus stated the difference between my view and the theory of Mr. Geikie as broadly as it can be stated, in order that we may both be compelled to refer to those facts of detail upon which safe conclusions can be based.

I had the honour in 1853[*] of laying before this Society a description of the phenomena presented by the ridges which separate the valley of Loch Awe from the valley of Loch Fyne. I showed that the structure of these ridges is such as to indicate conclusively that the slaty strata have fallen inwards, or subsided towards the valley of Loch Awe, that when this movement took place they were already in their present hardened, crystalline, and metamorphic condition, and that, when so falling, great masses of porphyritic granite had risen along the planes of deposit, which would be the lines of least resistance, and, lastly, that when these granites so rose they were in a soft and viscid state. Let me shortly recapitulate the facts which indicate these conclusions.

In the first place it is a fact that all the slaty strata dip more or less steeply towards the valley of Loch Awe.

Their escarpments are everywhere presented to Loch Fyne, and the slope side forms the south-east bank of Loch Awe. In the second place, the summit-ridge is everywhere composed of these beds, and there the dip is steepest. In the third place, the lower and intervening ridges between this summit and Loch Fyne are generally rounded bosses of porphyry, which the slaty strata underlie and overlie conformably. In some few places the beds of slate or limestone are

[*] Quart. Journ. Geol. Soc. vol. ix. p. 360.

thrown off in contact with the granite ; but generally, and, indeed, almost universally, there is no difference in the dip of the strata either under or above the porphyritic ridges ; and not unfrequently the two rocks may be seen in juxtaposition, the slates dipping underneath the porphyritic masses, and again lying at the back of those masses and resting upon them.   In the fourth place, in the quarries of this porphyry, at least in one quarry, abundant fragments of the slates are found imbedded, having evidently been taken up by, and involved in, the flow of the porphyry when it was rising through or being squeezed through the passages of the falling strata.   In the fifth place, these fragments are of precisely the same mineral character as the parent rocks from which they have come ; they exhibit the sharp angles of original fracture as fresh as if they had been broken off yesterday, and have evidently never been themselves altered, nor have they effected any alteration in the paste into which they fell. I have already remarked on the immense importance which attaches to the question of the mineral condition of the slates of the West Highlands at the time when subterranean movements folded them and contorted them, and drove them into waves like water driven by the wind.   If that mineral condition was at all like that in which they now exist ; if they had already attained a hard and crystalline structure, then their liability to fracture along the lines of extreme tension must have been very great.   Mechanical laws render it certain that such fractures must have accompanied the strain and pressure to which they were subjected.   The evidence, therefore, which shows that the slates were just what they now are in texture at a time when the subjacent porphyries were in a soft and viscid condition, and the further evidence which shows that (in strict conformity with the results we should expect from the respective conditions of the two mineral masses) the porphyries were splashed up along the lines of deposit as the slates fell inwards—this evidence, I say, throws a flood of light on the whole problem we are now considering.   It shows that the mineral condition of the porphyries was precisely such as would facilitate the transmission of earthquake waves ; and it shows not less clearly that the mineral condition of the slates was such as necessitated fractures and dislocations when such waves were propagated underneath them.

But whatever may be the import and interpretation of such facts as these, certain it is that Mr. Geikie takes not the slightest notice of their existence.   The very illustrations he selects in support of his own theory show that he has paid no attention to the whole class of facts connected with the relative position of the mineral masses. Let me take as a conspicuous instance the Pass of the Awe.   Mr. Geikie mentions it as an example of his favourite theory that transverse valleys have been cut backwards by two streams originally running in opposite directions, until by the destruction of the dividing ridge one long continuous glen has been the last result.   The very words in which he describes this Pass give an altogether erroneous idea of its character as a feature in physical geography.   "The present outflow of the lake through the deep narrow gorge of the

Pass of Brander is, comparatively speaking, recent. It has been opened across the lofty ridge that stretches from Kings House through Ben Cruachan to the Sound of Jura." Every one reading this description would suppose that this " lofty ridge" was one of tolerably equal elevation along its whole length, that the Brander Pass had been cut across it in the middle, and that there was nothing to indicate any particular rupture of continuity *arising out of geological structure* at the particular point where this " deep gorge" occurs. No one would guess that, instead of lying across a continuous ridge, it occurs at the end and termination of the great mass of granitic mountains which stretch with but little interruption from Loch Rannoch, through the region of Glencoe, and terminate in Ben Cruachan. But there is nothing like a continuation of this ridge on the other side of the Brander Pass.   On the one side rise the highest mountains in Argyllshire, and one of the highest mountains in Great Britain. On the other side is a comparatively low range of hills, wholly different in geological structure.   I do not say that this general fact is conclusive against Mr. Geikie's theory ; but at least it has some bearing upon that theory, and ought to have been mentioned and explained. Of course when a deep gorge occurs at the dividing line between two different mineral systems, the idea is suggested to the mind that this change of structure may possibly have something to do with the fissure which marks its site.   Still more clearly, when this deep gorge marks the termination of great upheavals, or, at all events (to use language which involves no hypothesis), marks the end of mineral masses attaining a great elevation, the idea of this sudden depression being due to subterranean force gains much additional probability.   But over both these significant facts Mr. Geikie passes in perfect silence.   And these broad facts being omitted, it was perhaps hardly to be expected that other facts, requiring still more detailed examination, but perhaps even more significant than any other, should be omitted also.

I submit, however, that it is a point of great importance to know the appearance which the slates exhibit along this line of junction.   It will be observed, in the geological map which is appended to Mr. Geikie's book, that the whole left bank of the Awe is represented as occupied by the mica-slates, and that on the right bank of the river also there is a narrow strip of the same material between the river and the great granite mass of Cruachan.   Now how do these stratified slates lie on the respective sides of the river ?   On the left bank they dip away from the Pass ; and its precipitous sides are composed of the escarpment of the strata broken and, as it were, gaping towards the opposite mountain.   On the right bank (that is, along the base of Cruachan) the same slates lap round the mountain and are tilted steeply against its sides, which rise so suddenly from the bed of Loch Awe that the road has to be cut into their flank.

I exhibit a rough section of the relative position of the mineral masses as above described. There are here, in my opinion, evident marks of fracture and dislocation. There have been, apparently, subsidences along one line, and corresponding elevations along another :

one of the islands in Loch Awe, at the foot of Cruachan, exhibits the mica-slates in a perfectly vertical position.   Loch Awe seems to have been an area of subsidence; and the gorge of the Brander Pass lies along the line of a great fracture connected with the subterranean movements which brought up the granites of Ben Cruachan.

Fig. 2.—*Section across the Brander Pass.*
Gorge of the Awe, or Brander Pass.
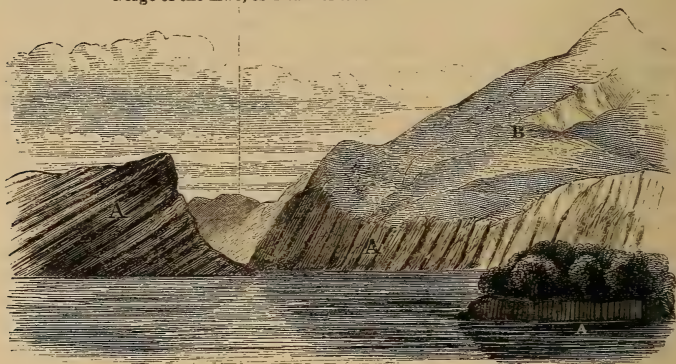
Loch Awe.   Island of Freuchlin.
                                       Slates perpendicular.

A. Mica-schists.   B. Granite of Ben Cruachan.

That fracture and dislocation of the strata have taken place is certain.   It is for the erosionists to prove that this fracture and dislocation was without influence in causing the " deep gorge " through which Loch Awe finds its exit to the sea.   It is for them to prove that the time when the subterranean movement took place was not also the time when the Brander Pass was formed.   I might multiply instances of the same kind without number.

Here I should observe, as an important fact, that although Mr. Geikie speaks of the Highland mountains being tossed into folds, or wave-like plications, I know of no instance in which the same beds are literally folded so as to bend over the top of a mountain and fold down into the valley beneath.   In all cases the beds which rise to the summit of the mountains are there broken, and present more or less rugged escarpments, in the direction towards which the undulation appears to have proceeded.   In short, they are, as Mr. Geikie says, very like waves; but then they are waves which have broken at the top—not the waves of a heavy ground-swell, but rather the waves of a sea vexed by the meeting of wind and tide.   This is as we should certainly expect if wave-like movements were ever propagated under a surface occupied by rocks already hardened and consolidated, as these mica-slates appear to have been when the subterranean movement affected them.

I shall now direct attention to another specific case in which Mr. Geikie has omitted all mention of the principal facts connected with the geological structure of the country.   He takes the trans-

verse valley of Loch Eck as another instance in which two streams,
each working backwards towards its own source, have finally de-
voured and carried off the ridge which separated them, and thus at
last converted two narrow glens into one broad valley.   Now the
first thing to be noted in regard to the whole district of Cowal, or
the mass of mountainous land which separates Loch Fyne from the
great depression which is occupied by the Firth of Clyde, is, that
whilst the dip of all the strata on Loch Fyne is towards the north-
west, on the shores of the Firth of Clyde it is precisely opposite, or
south-east.   The intervening mass of mountains is therefore the
seat of a great anticlinal axis.   Sir R. I. Murchison first pointed out
to me that a magnificent section across this anticlinal is presented
along the banks of Loch Eck.   This would not necessarily account,
however, for a valley which runs not along the anticlinal, but across
it.   In an area, however, of great disturbance, where, as in this
case, there is every mark of the beds having been subjected to the
most violent tension from subterranean movement, transverse cracks
and subsidences must be always liable to occur.   But in any case it
is a district of great disturbance ; and where this is the case it is a
gratuitous assumption to attribute a transverse valley to forces which
are comparatively inadequate to the work.   I have pointed out how
entirely Mr. Geikie avoids giving us any description of structural
detail when he deals with hills and valleys, when that detail is ad-
verse to his theory.   But there is one valley in the Highlands in
respect to which he does enter into much detail, and gives us a
special diagram setting forth its structural peculiarities : it is the
valley of Loch Tay.   The valley, he says, now runs along the top of
an anticlinal axis, so that, as he expresses it, that which geologically
is the top of a mountain is geographically the bottom of a glen.
The mountain of Ben Lawers, which rises above the lake, is repre-
sented as exhibiting beds forming structurally a synclinal trough,
and yet, in physical geography, constituting an isolated mountain cut
out of the thickness of the rocks which once surrounded it and have
all been washed away.

    Now, in regard to this case, on which Mr. Geikie lays great stress,
and from which he jumps to the largest and most general conclu-
sions, I have several observations to make.   In the first place, not
believing as Mr. Geikie seems to do, that all the hills and valleys in
the Highlands can be accounted for by any one theory as to the phy-
sical agencies concerned in their production, I should be quite
prepared to admit, upon adequate evidence, that Loch Tay has had a
wholly different origin from Loch Awe, and that the processes which
formed Ben Lawers have been wholly different from those which
formed Ben Cruachan.   In the second place, I have to observe that
even the facts of this case, as given by Mr. Geikie, are quite capable
of a different interpretation from that which he assigns to them.
It is not only possible, but in the highest degree probable, that a
valley due to fracture should lie along the top of an anticlinal axis.
That is precisely the line along which hard crystalline rocks would
be exposed to the maximum of tension, and therefore along which

they would tend to break and gape. In another passage our author himself admits that " the coincidence of a valley with an anticlinal axis may perhaps be traceable to an actual fracture of the strata along this line of severe tension." But, in the third place, I have to observe that although I am not personally acquainted with the Loch-Tay district in minute detail, I do know enough to be sure that Mr. Geikie's facts are at least exceedingly incomplete. As usual, he avoids all allusion to the occurrence of granite, or other rocks usually regarded as eruptive; and from his description and sketch no human being would suppose that they make their appearance anywhere on the bank of Loch Tay. Now I happen to know that the southern banks of Loch Tay constitute a district of much disturbance, large masses of granite and porphyritic rocks charged with metalliferous deposits appearing through the slates, and indicating some great subsidence of the strata. I do not, indeed, know how these strata lie with reference to the granites, whether they underlie them, as in the case near Inverary, or whether the slates are thrown up and tilted against those masses as along the foot of Ben Cruachan. But these are precisely the facts which Mr. Geikie ought to have supplied, because they are the facts on which the whole question of mechanical causation of hill and valley may depend. I attach no value whatever to a theory which passes over and ignores this class of facts altogether.

I now proceed to notice, in the last place, one rather obscure argument on which much stress is laid in support of the theory that all our hills and valleys are due to erosion. Mr. Geikie says that there is a wonderful symmetry in the general structure of all river- and valley-systems; one glen branches off from another, and all conduct their waters to the common goal, which is the sea: and then, in looking on the hills from some distant point, or from one of their own higher summits, he sees a wonderful and mysterious average in their height. This symmetry of structure in the glens can only be due, it is said, to the trickling of water, just as we see it in wet sand which the tide has left; and so in like manner this general average of height can be nothing but the once uniform level of the great mudbank when it rose above the sea. My answer to this argument is, first, that the hill-and-valley system of the Highlands is not in the least like the symmetry of rills oozing out of, and cutting their own way through, wet sand; secondly, that such symmetry as does exist is more easily accounted for by a totally different explanation.

First, then, the symmetry, whatever it be, is not of the kind which would be made by water merely cutting its own shortest way to the sea. The tributary streams in the Highland glens join each other and the main valleys at all sorts of angles, and from every point of the compass; and their course appears to be invariably determined by heights and ridges which they are compelled to run *round*, because they cannot run *through*. In the next place, such symmetry as does exist is due, by the confession of Mr. Geikie himself, to geological structure; because he admits, as we have seen, that the longitudinal system of valleys follows the strike of the

strata, which strike has been determined by the geological and sub-
terranean force which tossed the strata-like waves from north-west
to south-east.

As regards, again, the argument derived from one general average
height, I must remark, in the first place, that the irregularities of
height are very great—that Ben Cruachan, for example, towers high,
head and shoulders above all the lower hills to the south and west,
that Ben More stands in the same relative position to the hills of
Mull, and so on.   Of course there is a maximum height in every
mountain-country ; and of course also a large number of the higher
hills make a more or less near approach to this maximum elevation.
But I entirely deny that it follows from this, or that any presump-
tion whatever arises from this, that the whole country was once one
great hog's-back or tableland at or near the level of what are now
a few solitary peaks, and that all the rest of the country has simply
been blocked out and cut away by the agencies of erosion.   Nothing
can be more certain than that from any given mechanical subter-
ranean force, acting on rocks of a given hardness over a given area,
a certain amount (and a very large amount) of uniformity would be
produced in the height and depth as well as in the direction of their
undulations.   If a powerful wave were to pass under ice so as to
break it up along certain lines of upheaval and depression, and if
the breaking pieces could be retained by some viscid matter in the
forms they would take in breaking, I apprehend that there would
be found a general average in the height to which they would
rise, and in the depth to which they would sink in the act of giving
way.   In like manner, if along several miles of country occupied by
a hardened crystalline rock, like mica-slate, there came an earth-
quake wave so powerful as to toss it like waves of the sea, it would
break along certain lines, and the height to which it would rise in
one place and sink in another would bear a definite proportion to
the amount of force and to the power of its own various beds to
bear different degrees of tension.   I see nothing whatever, therefore,
either in the average height of the Highland hills, or in the sym-
metry of the valleys, to compel me to adopt the extreme opinion ad-
vocated by Mr. Geikie.

I cannot conclude this paper without observing on the assumption
made by him that his own theory has the exclusive merit of resting
upon the " known and visible causes of change," whilst all who differ
from him have to imagine the former existence of other causes far
more stupendous " merely " because the results achieved seem other-
wise " inexplicable." My complaint of Mr. Geikie's theory is precisely
this—that it is not based upon the known and visible causes of change
"as these are revealed by their known and visible effects." For, of
course, it is in this sense alone that we can speak of either class of
agency as now " visible " in the Highlands. True it is that we do not
now see them moved by subterranean force. But neither do we now see
them sculptured by enormous glaciers. The frosts of Greenland are
a visible cause of change ; but so are the fires of Hecla. Neither of
them now affect the area of the Highlands. But Mr. Geikie con-

fesses that this area was once, at some time or another, the sport of
forces compared with which the most furious volcanic outbursts of
our time are feeble indeed,—even of forces which tossed and crum-
pled its strata, like waves of the sea driven before a N.W. wind.
But, besides this, he insists upon it that the Highlands have been sub-
ject to a force not only much more stupendous than any we now see
in operation there (for this I fully admit), but far more stupendous
than any of the kind which can be proved to exist, or ever to have
existed, in any portion of the world. My objection, therefore, to Mr.
Geikie's theory is, that out of several causes of visible change he
gives an undue preference to some one or two, ascribing to them effects
which they are not proved to be capable of producing, and refusing
to other causes of change, which are equally known and visible,
effects which are within their easy reach. It is significant of the
partial and erroneous view which he takes of the relation between
different known causes of change, that when he lays down the abs-
tract general principle which we should bear in mind when we are
speculating on these subjects, he states that principle in language
which is erroneous. "In all such attempts," says Mr. Geikie,
speaking of theories opposed to his own, "we make the fatal error of
forgetting that, in the geological history of our globe, 'Time is
Power.'" Of course, in a loose popular sense, this is true; but
speaking strictly and philosophically, it is altogether incorrect.
Time does nothing by itself, nothing except by the aid of its great
ally Force: Force working in Time—this is one conception of all
change, or rather of that which produces change. But then due
account must be taken of all the kinds of Force which the records of
time reveal. Each special kind of force has its own special effects,
and very often these can be produced by none other. We know that
Force has been acting always, in all forms and in all degrees. When
we have before us given ascertained mechanical effects, it is indeed
a rude philosophy which would ascribe them to any given kind of
force, merely on the ground that by this force they could be done in
the shortest time. But the philosophy is quite as rude which would
select as the cause of those effects some other favourite kind of force,
on no other ground whatever than that by this force the operation
would consume the longest possible amount of time. It becomes not
only rude, but perverse, when the force selected for this preference
is one which has never been proved to be capable of producing such
effects at all. No one appreciates more highly than I do the labours
of those older geologists who first taught an earlier generation to
estimate more truly the power and efficiency of certain forces which
act very slowly but continuously during long periods of time. The
error in scientific speculation against which they fought was the
error of laying exclusive or exaggerated stress upon forces of a par-
ticular kind—forces the existence of which they did not deny, but
which had worked only at comparatively distant intervals, and in
alliance always with other forces, the operation of which is ceaseless.
It is precisely the same error in principle, though exhibited in a dif-
ferent form, which is now exhibited by those geologists who attribute

almost everything to running water and to scraping ice. They are simply Catastrophists in a new dress. They attribute extravagant power and stupendous effects to one form of force instead of to another.

There is, indeed, one difference, and it is a difference in favour of the older school of Catastrophists rather than of the younger—that whereas there never could be any doubt of the adequacy of subterranean force to produce the effects ascribed to it, there is the greatest doubt of the adequacy of rain and ice to effect in any time, however long, the stupendous changes ascribed to them by Mr. Geikie. On the other hand, there is really nothing stupendous about those effects when they are regarded in connexion with the known and visible effects of subterranean force. The highest ranges of mountain we have are, relatively to the circumference of the earth's crust, infinitely smaller than the puckers on an orange-skin.

The smallest amount of shrinkage, earthquake-waves and commotions of comparatively the gentlest and feeblest kind would suffice to produce the tossings of the Highland Hills. Magnitude is all relative. The store of Time and the store of Force may be regarded as both unlimited. But it does not follow that in accounting for any given effect we are entitled to draw to an unlimited extent either upon the one or upon the other. Extravagant demands may as easily be made upon the one as upon the other. The inventions and imaginations to which the extreme Glacialists resort are, beyond all comparison, more violent than those which were common with the old Convulsionists. Whole continents are built up upon the top of the existing mountains, where there is no proof whatever that they ever existed; and then these continents are all ground down by ice, or washed away by ordinary surf, and yet so that not a fragment shall be left behind. I venture to believe that I shall have some support from the great leaders of geological science, who, in power of intellect, are still young among us, when I record my dissent from the extravagant theories of the younger Glacialists.

FEBRUARY 26, 1868.

David Homfray, Esq., Port Madoc, was elected a Fellow.

The following communications were read:—

1. *Observations on the* PARALLEL ROADS *of* GLEN ROY. By CHARLES BABBAGE, Esq., F.R.S.

(Communicated by the President.)

Many years have passed since I visited the remarkable scenery of the parallel roads of Glen Roy. Several explanations of their origin have been given; and my own view of the subject was, I apprehended, in accordance with the views of geologists. The recent paper of Sir John Lubbock upon that subject shows that the causes which have hitherto been assigned for their origin have not yet received general assent. Under these circumstances, I think it desirable to record the very simple explanation of their origin which had satisfied my own mind.

In the largest of a system of valleys many hundred feet deep and whose sides are very steep, there occur three lines of terraces at different heights, each apparently preserving its horizontality over an extent of above twenty miles.

The sight of these extensive parallel lines immediately suggests the idea either,

1st, that they had arisen from the beaches of ancient lakes which had formerly filled the intervening valleys, and that the levels of those lakes had at distant intervals been reduced by the bursting of successive barriers by which their waters had been confined ; or

2ndly, that they had formed the beaches of a system of fiords, or narrow inlets of the sea, which had been elevated at various times by internal heat.

The first of these suppositions is, I believe, most generally adopted ; and it appears to me to be the most probable.

These parallel roads themselves slope gently inwards towards the central valley. They are about 50 feet broad, and consist of the same angular fragments of stone as those which rest upon the slopes above them. No one who has seen them can doubt that they are the result of water-levels ; and the bursting of successive barriers seems to be the most probable cause of their existence.

But the difficulty still remains of accounting for the origin of such beaches resting upon the sloping sides of very steep mountains and themselves covered with fragments of the rock on which they repose.

When these valleys were occupied by water, the lakes were not sufficiently large to allow of the formation of a beach by the action of their waves.

If such lakes had existed in a climate in which their *waters were never frozen*, the rain which poured upon the upper part of the surrounding mountains might certainly in a long course of years have washed down their sides a multitude of the fragments similar to those now lying upon their steeply inclined surface. The winds also would have contributed to this transfer of the loose stones from the higher and more exposed portions of the mountain to lower levels. Under such circumstances the detached stones, notwithstanding occasional impediments, would descend with a continually increasing velocity. On reaching the surface of the water they would plunge obliquely into it, still advancing until, their horizontal velocity being destroyed by its resistance, they would fall vertically to the bottom.

If such lakes had existed in a climate in which *they were occasionally frozen, but in which no snow fell*, then the oblique impact of the stones detached by the wind or rain would cause them to rebound from the surface of the ice, and advance by a series of bounds far beyond the margin of the lake.

If such lakes were situated in a climate in which the *mountains above them as well as the lakes themselves were occasionally covered with snow*, then the slow melting of the snow upon the upper parts of the mountains would lubricate their surface. The snow itself would gradually subside, carrying with it many of the loose

fragments of stone, until it might at last even sweep down in little miniature avalanches, and thus cover the *edges* of the frozen lake with a multitude of loose stones which had previously rested upon the inclined surface of the mountain, and even with some of those imbedded in its soil.

Thus a mound of snow containing the débris of the mountain itself would be formed round the margin of the lake during the winter. On the return of summer, this margin of snow as well as the icy covering of the lake would slowly melt, and the accumulated débris of the mountain above it would thus be quietly deposited in the still water on the margin of the lake.

An analogous case, arising in its commencement from the same causes, although differing in its ultimate results, occurs when the snow falling upon the higher elevations of great mountain-ranges accumulates, and from time to time rolls down their sides in enormous masses, carrying with it the fragments of rocks which were loose upon their surface, and tearing up others more or less firmly attached. The valleys thus filled up are called " glaciers ;" and, the same causes continuing to act, there are often formed upon their surface one or more lines of these broken fragments of rocks near the edge of the glacier, which are then called " moraines."

The parallel roads of Glen Roy are, in my opinion, the results of ancient moraines, generated by rain and snow, upon a very contracted scale.

It has been observed that in the highest portions of glaciers the substance of which they consist is opaque ; it is, in fact, condensed snow ; whilst at the lower ends of the glaciers which terminate in alpine valleys, the opaque structure of the condensed snow has been changed into clear transparent hard ice.

This transformation, which I have explained more fully elsewhere[*], arises from the circumstance that the masses of frozen snow in their transit down valleys many miles in length, are continually cracked and split, generally in vertical planes.

The friction of the fractured sides against each other generates heat sufficient to melt a small portion of the indurated snow. The water thus produced is retained within the narrow fissures, or is spread over the surface of the opaque ice and freezes very slowly. It therefore becomes a thin layer of *transparent* ice.

The ice thus formed is much *harder* than the opaque snow-made ice, which is full of bubbles of air ; consequently, when the next move down the valley produces a new fracture, it will not occur in the transparent ice, but in the opaque consolidated snow.

Thus in their long passage down the glacier the blocks of condensed snow are gradually converted into pure transparent ice. At the lower end of one of the glaciers, I was enabled for a short time to get close to some of the terminal blocks. I could distinctly trace in these the wave-like structure of the transparent ice. The preceding explanation rests upon the passage of matter not in a state of fluidity, nor yet altogether solid, over substances of a harder nature.

* Passages from the Life of a Philosopher, chap. xxxiv. p. 464: 8vo, 1864.

In a similar case the transit of winds over extended sandy plains leaves behind wave-like elevations in the form of sandy dunes. I remember at a very early period of life having my attention strongly fixed upon the curious gyration of very fine sand acted upon by a continuous breeze.

Upon a level plain of several hundred feet in length and breadth, covered with a thin layer of very fine sand, I observed a series of little vortices, each about 6 inches in height, all revolving rapidly about their axes in the same direction. Each after the lapse of a short time disappeared, and others continually arose. Unfortunately I did not observe the character of the surface of the sand over which these miniature whirlwinds traversed.

I now return to the second theory—that of the rapid elevation of a group of islands above the level of the sea at several distant intervals of time. If this view of the subject is adopted, it becomes necessary to assign a cause capable of producing such an effect. Many years ago I had arrived at such a cause, to which I will now refer, although I do not think it the true cause of these parallel roads.

During a visit to Naples, in the early part of the year 1828, I had an opportunity of examining the remarkable changes of level which had taken place in the Bay of Naples, and in the surrounding country, more especially those indicated by the remains of the Temple of Serapis, which greatly stimulated my curiosity to inquire into their causes. I had also descended into the crater of Vesuvius, then in a state of active eruption, and measured a base of 340 feet, by which I ascertained its depth to be at that time about 500 feet.

These comparatively recent geological occurrences within the period of history formed a connecting link with far more remote changes which geology had clearly established. I felt therefore the want of some definite principle which should be alike applicable to the whole series of geological changes.

This led me in the latter part of the year 1829 to a generalization which I expressed shortly by calling it *the theory of the change of isothermal surfaces within the earth.*

At a later period, at the request of Dr. Fitton, and in accordance with the wishes of Sir Henry De la Beche, I drew up a paper on the subject, which was read at a meeting of the Geological Society on the 12th of March, 1834. I shall only extract four lines, taken from the 'Proceedings' of the Society.

" Mr. Babbage's theory therefore may be thus briefly stated :—In consequence of the changes actually going on at the earth's surface, the *surfaces* of equal temperature within its crust must be continually changing." (Proceedings Geol. Soc. 12th March, 1834.)

Another important consequence necessarily results from this principle—that the continual transfer of matter to different situations upon the earth's surface and to different distances from its centre must continually, though very slowly, alter the position of its centre of gravity, and also the position of its poles upon its surface. Hence it follows that, in penetrating through a succession of strata

at any part of the earth's surface, we might even find indications of tropical and of polar climates alternating with each other in any order of succession. But the theory of the continual change of isothermal surfaces is not confined to the narrow limits of the planet we inhabit. Wherever the causes I have referred to are in action, similar changes must be taking place. Our own satellite as well as all those attached to planets in our own or in other systems obey the same law. There is sufficient evidence that the amount of the radiation of heat from the sun itself is continually changing. This change will necessarily cause analogous changes in all its dependent planets. The stars themselves in many cases have given indication of change in the intensity of their light. In one or two instances a star has almost suddenly become brilliant, and after a short period nearly resumed its former appearance.

I have entered thus fully into the history of *the changes of isothermal surfaces within the earth,* because, during a late visit to Cambridge, my valued friend Professor Sedgwick informed me that he always concluded his annual course of geological lectures by explaining " *Herschel's theory of the change of the isothermal surfaces within the earth.*" I referred him to the dates, and informed him that, whilst I fully admitted the originality of my friend's discovery, I claimed for myself its long previous discovery and publication. I delayed the printing of a treatise then going through the press. I caused woodcuts to be made to illustrate Sir John Herschel's letter to Sir Charles Lyell, and was the first to publish my friend's subsequent, although *quite independent,* discovery to the world, in the Notes to the first edition of the Ninth Bridgwater Treatise. The date of the Preface to that work is April 1837.

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
2. *On the* ORIGIN *of* SMOOTHED, ROUNDED, *and* HOLLOWED SURFACES *of* LIMESTONE *and* GRANITE. By D. MACKINTOSH, Esq., F.G.S.

<div align="center">(Abstract.)</div>

THE author, believing that late discussions on denudation have reached a stage which requires that the respective claims of rainwater and sea-waves to mould rock-surfaces should, as far as possible be set at rest, proceeds to state the results of his observations as follows :—

" Unless rain-water be retained for a certain length of time in previously formed hollows, it can exert little or no chemical influence on rock-surfaces ; and therefore the principal, if not all, the inequalities found on the sloping or vertical sides of fragments, blocks, or faces of rock must be either the original fractured surfaces, or produced by some kind of mechanical action. Rain-water, uncharged with solid matter, such as sand, can exert little or no mechanical power on hard rocks. The chemical action of rain-water can enlarge previously formed hollows ; and where retained for a sufficient time, it can dissolve out fossils, and develope the structural form of rocks. Rain-water, not concentrated into streams of sufficient force,

can never, either chemically or mechanically, produce a smooth and regular surface by shaving away hard and soft parts alike, or by cutting equally through crystals of a different nature, but must always leave a surface minutely corresponding to the denudability of the parts (of the crystals) of rocks; it can only roughen, or leave a surface more or less zigzag in profile. In Devonshire and elsewhere, on all granites used in building, atmospheric weathering leaves a surface rough in proportion to the size and varied nature of the crystals, and never a smooth or uniformly curved outline."........ "A smooth or polished surface (not involved in the structure of rocks) whether a plane ————, a curvilinear hollow ⌣, a curvilinear protuberance ⌢, or a curvilinear hole ○, can only be produced (leaving ice at present out of consideration) by human agency, or naturally by water charged with sand or stones, and acting with a force sufficient to overcome inequalities of structure to a certain extent." The author verified these statements by appealing to the street pavements, or curbings of granite and limestone, in Exeter, Dawlish, and Teignmouth. He then described moulded surfaces of limestone both exposed and protected by red loam, on the Mendip Hills. "They resemble works of art in consisting of curvilinear heights, hollows, through-perforations, and grooves. The figures are often geometrically exact. The hollows vary in depth, from shallow saucer-like depressions to pot-shaped cavities. The through-perforations are sometimes more than a foot in diameter, more or less funnel-shaped, and as smooth and regular as if turned out in a lathe. No phenomena at all resembling them are now in course of being formed, excepting on sea-coasts, and in the channels of rivers." "Fac-similes of them are to be found on many sea-coasts at the present day." They are *ground* out by the gyratory action of waves charged with sand, or by waves wielding a stone or stones.

The author concluded by describing an extraordinary assemblage of regularly arranged limestone flags, like grave stones, with natural inscriptions consisting of grooves generally parallel, but often bending round at nearly right angles—both trough-shaped and running the whole length of the flag—very smooth and regular in form, their profile resembling the letter U. He believed they could not be explained by the action of land-ice, and thought that the theory of the to-and-fro motion of sea-waves, laden with coast-ice charged with stones, offered the most satisfactory explanation of all the phenomena. They may be seen a short distance to the west of Minera, near Wrexham, on a limestone tableland marked Ty hir on the Ordnance map.

3. *On a* STRIKING INSTANCE *of* APPARENT OBLIQUE LAMINATION *in* GRANITE. By D. MACKINTOSH, Esq., F.G.S.

(Abstract.)

IN this paper the author draws attention to the resemblance, at first sight, presented by many of the tors and cliffs of granite on Dartmoor, to the forms assumed by the Millstone-grit in Yorkshire,

and states that, among the former, the apparent lines of lamination and stratification are often as distinctly marked as in the latter. His object, however, is not to defend a theory, or to deny that certain granites may be of directly igneous origin and intrusive, but to bring into notice several phenomena in which the *linear structure* of granite seems to suggest the idea of original aqueous deposition :—(1) a semidetached portion of one of the ranges of cliffs called Hountor Rocks, in which there is the appearance of strata embracing laminæ, the second stratum obliquely denuded, a third thrown down on an inclined plane, and horizontal deposition resumed in the fourth or uppermost stratum ; (2) the Kestor Rock, near Chagford, the apparent lamination of which is, in several places, obliquely crossed by fractures of the nature of joints ; (3) the Blackenstone Rock, which presents a very regular series of beds ; (4) the Hey Tors, especially the western boss of rock, in which two very different kinds of granite are separated by a distinct line parallel to the lines of apparent lamination and stratification below and above.

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4. *On the* MODE *and* EXTENT *of* ENCROACHMENT *of the* SEA *on some parts of the* SHORES *of the* BRISTOL CHANNEL.   By D. MACKINTOSH, Esq., F.G.S.

CONTENTS.

1. *Introduction.*—In a paper read before this Society, Nov. 8th, 1865*, Mr. Godwin-Austen brought forward very satisfactory reasons for concluding that the area of the Bristol Channel was dry land during the (now submarine-)forest era, and that it must afterwards have subsided to a depth of at least 120 feet, as a submerged

Fig. 1.
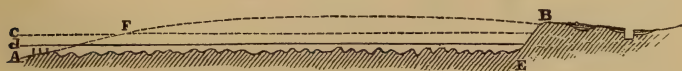
land-surface is now found at that depth under the sea-level. Whatever relative changes in level the land and sea may have subsequently undergone, it is obvious that the general tendency of the waves and " ground-sea " or " Atlantic drift " (which is sensibly felt beyond Watchet) has been to destroy the contour of the gradually rising shores by wearing them back into cliffs.   As a consequence, the extent of the encroachment, since the forest-area went down, may, in some localities, be approximately ascertained.

2. *Form of Sea-coast near Watchet.*—Let Fig. 1 represent a trans-

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* See Quart. Journ. Geol. Soc. vol. xxii. p. 1.

verse section of the coast immediately to the east of Watchet harbour (looking east); AB the supposed surface-contour when the forest-area was first submerged; c, the possible level of the sea during the Scrobicularia-mud period (which must have been relatively higher than at present); d, the present high-tide level; E, Infraliassic (?) strata.   The sea would begin by making a line of cliffs at F, which it would wear backwards and downwards as the land gradually rose to its present altitude.   In this way, I think, there can be little doubt the great mass of strata A E B F A has been denuded; so that the sea has not here overflowed a subsided area, but really encroached on the land.

3. *Extent of Strata removed.*—The average height of the cliff E B is at least 50 feet.   The bare rocky bottom of the sea, I have been assured, extends nearly a mile from the cliff in the direction of A ; and there the first traces of the submarine forest, consisting of upright stumps of trees, &c., have been found.   As in scientific inquiries it is better to underrate than the contrary, if we suppose only half a mile to intervene between the stumps A and the cliff E (and I have met with no one who would not regard this as an underestimate), it will be obvious that the sea has recently had no small share in the denudation of the Bristol Channel, whatever may have been the cause of the original excavation.   A continuance of the present mode and direction of encroachment would entirely remove the high ground between Watchet and Williton, and wear back the slopes of the Brendon hills into towering cliffs.   Taking other parts of the coast, where similar encroachments are in progress, into consideration, it may safely be inferred that a sufficiently prolonged occupation of the Bristol Channel by the sea would enlarge it to a very great extent.   It is likewise obvious that many wide-spreading plains with steep escarpments at intervals, now far inland, may have been formed out of river-valleys by the sea wearing back its cliffs, and that this may even have taken place in situations comparatively sheltered, as is the case with the Bristol Channel at the present day.

4. *Recent rate of Encroachment.*—I learned from a very old fisherman at Watchet, whose veracity no one seemed to doubt, and whose statements concerning the encroachments of the sea were directly or indirectly corroborated by others[*], that not more than 150 years ago a brewery, belonging to a Mr. Davies, stood at a distance of at least 200 yards from the present cliff east of Watchet harbour, and that rocks under its site are still recognized.   There was likewise a village (hamlet?) called Easenton, to which the fisherman's great-grandfather was in the habit of going for a mug of beer, the site of the furthest east part of which is now about a quarter of a mile from the coast.   To the west of Watchet, the sea is encroaching on a high ridge and undermining large blocks of sandstone interwoven with alabaster, which it carries entirely away, or scatters and piles

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[*] I found the following record among the documents of a solicitor of Williton:—North of Raclose [a part of Watchet] in 1662, a barn and other buildings, with orchard and garden beyond.   In 1751, all gone to sea.

up in strange confusion.   Under the lofty cliffs there is, generally
speaking, a block-beach—further seaward, shingle and sand, often
alternating along-shore—then rocks more or less covered with clay
or silt, succeeded by ridges of bare rocks, like natural breakwaters,
which extend seaward to a great distance.   The bed of the sea,
here, is far from being level, though the inequalities, it is true, are
on a small scale.   At intervals along-shore there are miniature bays,
which are concealed at high water.   Indeed the configuration of
the sea-bed under and for some distance from the cliffs very much
resembles the uneven ground at the base of many inland escarpments.
Beyond Blue Anchor, the old forest-ground rises out of the sea,
passes under a ridge of shingle, and runs along the adjacent valley.

5. *Raised Sea-bed.*—Immediately to the east of Watchet a greater
or less thickness of gravel may be found filling up hollows in the
Infralias (?).   It consists of well-rounded pebbles of quartz, Old Red
sandstone, Devonian slate, &c.   Further eastwards, in Doniford Bay,
it attains a thickness of at least 20 feet, with a covering of about
4 feet of loam.   Its surface there inclines in an easterly direction
until it passes under the sea-level.   Landward it extends along the
valley leading to Williton, or thins out against the slopes of the hills.
Near Watchet it rises to a level above the sea of at least 50 feet.
Is it of the same age as the shingle of the so-called raised beaches?

6. *Encroachments near Weston-super-Mare.*—The sea is converting
slopes into cliffs, where it is not silting up flat areas*, from Brean
Down to a considerable distance northwards.   Both sides of Brean
Down (the outcrop side and dip side) bear witness to its action.
On the latter the appearance of a terrace about 30 feet above high-
water-mark strikes the eye at a distance.   It has been regarded as
a " raised beach "; but I am not aware that it has ever been particu-
larly examined.   Near Weston, the sea is forming a line of cliff on
the north-western side of Weorle Hill, which runs nearly parallel
to what appears to be an old line of sea-cliff near the top of the hill.
At Birnbeck Cove its encroachments have disclosed, or rather nearly
destroyed, the last remnants of a genuine raised beach, which, as it
may soon be no more, deserves a brief description.   I found it repre-
sented at intervals along the top of the cliffs from the Flagstaff, as
far as the bathing-cove, by small rounded flints, angular flints like
chips or flakes, angular fragments of limestone, and loam, in places
covered with a thin layer of rounded stones—the whole associated
with land- and sea-shells (*Littorina* and *Tellina*).   The raised
beach assumes its most decided character in Birnbeck Cove—a small
recess, which in stormy weather is one day choked up with blocks
and shingle, and the next cleared out by the sea.   A brief description
of the raised beach has been given by Mr. Day in the 'Geological
Magazine' (March, 1866), with a theoretical transverse section.   I
subjoin a front view in Fig. 2.   It rests on the upturned and denuded

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* As a general rule, where conditions are favourable to both processes, the
sea silts up valleys and denudes hills.   Alternately, along-shore, it acts as a pre-
server and destroyer of land surfaces.   This fact, I think, ought to be borne in
mind in speculating on the action of the sea during the glacial submergence.

edges of strata of limestone, and a conformable mass of trap from 30 to 40 feet thick*.

Fig. 2.

Present Sea-beach.

1. Reddish loam with angular and sub-angular stones, 4 feet.
2. Concretionary layers of sandstone, 2 feet.
3. Layer of nearly pure sand, 1 foot.
4. Conglomerate and breccia, consisting of rounded, subangular, and angular stones (with occasional flint chips) imbedded in a hard ochreous matrix, with sea-shells, and in the upper part numerous bones. The stones sometimes lie loose, but in general are firmly fixed. Thickness about 4 feet.

A. Arenaceous Limestone.
B. Limestone.
B'. Hard Limestone (metamorphosed?).
C. Trap from 30 to 40 feet thick.
D. Sand with a few layers of stones.
E. Raised beach exposed.
F. Raised beach concealed under falling débris or grass.

7. *Posttertiary Submergences.*—A submergence of between 25 and 35 feet, such as that indicated by the raised beach near Weston, would throw the plains or mud-flats near Weston, Clevedon, Burnham, Bridgewater, &c. under a considerable depth of water. During the time or times these flats were submerged, the caves situated within reach of the waves would necessarily become more or less rounded and smoothed, if not mainly excavated. Mr. Pooley, F.G.S., of Weston-super-Mare, lately discovered a cave (now built over) near the sea-level, at Southside, Weston, the sides of which were corniced with smooth, parallel and horizontal grooves. Mr. Pooley tells me that similar cornicings may be seen in the caves near Loxton. The cave in the face of the cliff near Uphill, described by Mr. Day in the ' Geological Magazine,' exhibits smoothly rounded and smoothly hollowed surfaces, with pot-shaped cavities. This, I ascertained, was likewise the case with a small cave at a lower level further south, which is partly filled with a loamy sand. The caves

* The trap, I believe, has hitherto been regarded as *intrusive*. But a comprehensive inspection, will, I think, show that it is a bed which, in a fused state, must have flowed over the limestone beneath, before the limestone above was deposited. Mr. Ravis, of Bristol, tells me there is a similar bed of trap in the limestone near Sandpoint, to the north of Weston.

among the Cheddar Cliffs furnish similar and even more convincing evidences, not only of the action of water, but of water so charged with solid matter as to be capable of grinding rock-surfaces. In these and other limestone caverns, the roof is often hollowed in such a way as to indicate a powerful and upwardly directed grinding agency, such as is now only possessed by sea-waves.

From the amount of knowledge hitherto collected, it would seem impossible to form a consistent scheme of the later oscillations to which the shores of the Bristol Channel have been subjected. The statements concerning Roman and other relics found under silt and peat near Bridgewater, and further towards the north, contained in the 'Transactions of the Somersetshire Archæological Society'*, cannot be consistently generalized by supposing any great changes in the relative levels of land and sea to have occurred in historical times; but, with a little allowance for inaccuracy, they can be included in a probable explanation by supposing that the natural or artificial embankments of the sea have, in different places and at different times, been breached, so as to lay the lower land behind under water for periods of greater or less duration, and that the extent of dry land has been increased by the growth of peat in marshes and a process of natural silting up, which causes an apparent retreat of the sea without any real change of level. A good section of the internal arrangement of the mud-flats was very lately (1866) furnished by digging a well, in presence of the author, near Mr. Candy's house, Lower Clevedon. Order descending:—

	feet.
Blue clay, with a few stones	10
Peat, with alder-branches and a few bones of deer (?).	$2\frac{1}{2}$
Fine light-coloured sand, thickness unknown.	

In the immediate neighbourhood, at the base of the limestone escarpment, the detrital covering of the hills seems to run under the sand.

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5. *On the* TWO PLAINS *of* HERTFORDSHIRE *and their* GRAVELS. By T. McK. HUGHES, Esq., M.A., F.G.S., of the Geological Survey of England.

CONTENTS.

1. *Introduction.*—The observations on which the following paper is founded were mostly made in the spring months of 1865 and 1866, while engaged in carrying on the Geological Survey of part of the neighbourhood of Hertford, and are now published with the permission of the Director-General of the Survey.

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* See references to some of these statements in Mr. Poole's article, Quart. Journ. Geol. Soc. vol. xx. p. 120.

2. *Physical Geography.*—As we stand on the high ground near Hertford Heath, Brickenden, Bayford, Essenden, or the upper part of Hatfield Park, we can hardly fail to observe that all those flat-topped hills, together with the high wooded country north-west of Bramfield and north of St. Albans, form part of a great plain extending as far as the eye can reach in all directions, the boundary of which is somewhere far beyond the district under consideration.

Out of this highest plain, a great valley has been excavated, the bottom of which itself forms another plain of very considerable extent, upon which Bayfordbury, Hertingfordbury, Bengeo, Bramfield, Cole Green, Welwyn Junction, and the lower part of Hatfield Park stand. The boundary of this lower or valley-plain is well defined. In the district under examination, it is bounded on the N. by the hills which rise suddenly behind Bramfield, on the W. by the hills which run from Welwyn to St. Albans, and on the S. by the hills which extend from Hertford Heath to Hatfield Park. It spreads out to the S. between St. Albans and Hatfield, and runs to the E. and S.E. by Ware and Parndon, while it probably extends round the base of the high ground behind Bramfield far to the N.E. Out of this lower or valley-plain the small and comparatively new valleys of the Rib, the Beane, the Mimram, and the Lea have been excavated.

The section (fig. 1) is drawn N. 15° W. and S. 15° E., through Hertingfordbury, from Brickenden Green, about three miles south of Hertford to Bright's-Hill Wood, about one mile north of Bramfield, and is intended to show the relation of the two plains to one another, and to the present river-valleys.

Fig. 1.—*Section from Brickenden Green, three miles south of Hertford, to Bright's-Hill Wood, one mile north of Bramfield.*

a. Boulder-clay.
b. Subangular gravel, sand, and loam of Lower Plain, with boulder-clay under it, in it, and on it.

c. Pebble-gravel of Higher Plain; large percentage of quartz.
d. Chalk and Tertiaries.
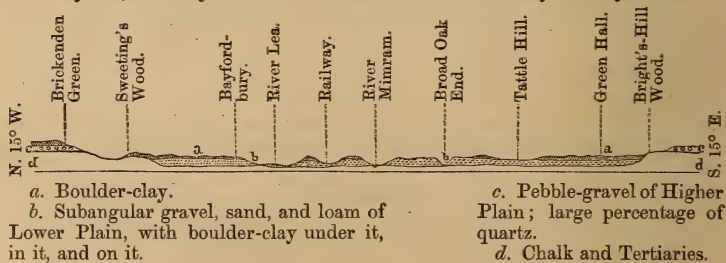
3. *Gravel of the Upper Plain.*—Now let us examine the characteristic Posttertiary deposits of these two plains, and see what light this will throw on their relative age.

The Boulder-clay rests on, *never under or in,* the gravels of the Upper Plain ; but, as it overlaps the gravel, and lies equally on the slopes of the hills and on the Lower Plain, its manner of occurrence only proves that the gravels of the Higher Plain are older than any Boulder-clay in that district.

The gravel of the Upper Plain consists chiefly of pebbles; of these, about fifty per cent. are of quartz, about ten per cent. of quartzite, about five per cent. various (such as jasper and a conglomerate of quartz pebbles in quartzite), and the rest flint. Sometimes the relative proportions of quartz and flint change places; but, as a general rule, if we take pebbles the size of an egg, we shall find a larger percentage of flint; and if we select those of the size of a pea, a larger percentage of quartz. There are just enough subangular flints and large partly worn pieces of quartz &c. to show that this gravel derives its pebbly character from the waste of older pebble beds, with which the unworn fragments got mixed, and not that they were all worn together into pebbles along the shingly shore of the Higher-Plain Gravel-sea.

From their great extent, persistent character, and uniform level, I think these gravels of the Higher Plain must be a marine deposit; but without a careful examination of the old coast-line, and of their behaviour as they approach the Crag country, I should not like to give any opinion as to their age.

They may be well examined at Queen Hoo Hall, Bright's-Hill Wood and elsewhere near Bramfield, at Hertford Heath, Brick-enden Green, Bayford, Berkhampstead, Essenden, and behind the kiln at Hatfield Park*.

4. *Gravel of the Lower Plain.*—The gravels, &c., of the Lower Plain vary far more in their arrangement and composition than those of the Higher Plain. Generally, they may be said to consist of about fifty per cent. of pebbles, of which about ten per cent. are of quartz, ten per cent. of quartzite, and about thirty per cent. of flint, derived from the Tertiaries or Higher-Plain Gravel. The remaining fifty per cent. are chiefly subangular flints with a few bits of ironstone, a few fossils from the Lias and Oolite, and a few of the black partly formed pebbles that occur at the base of the London clay. These subangular flints look as if they had been broken and weathered by surface-action, and are such as might be derived from any exposed flinty soil. Occasionally we find flints hardly rolled or broken at all, as if they had been derived directly from the chalk, or from the Boulder-clay, which often preserves them in that state, and had only suffered such decomposition of the surface as would result from their lying in the porous gravel. There is frequently a great quantity of false-bedded sand; and about the middle of the deposit we often, indeed generally, find a bed of brown loam and clay, passing sometimes into Boulder-clay, with, as usual, drifted Oolitic fossils, rolled and scratched lumps of chalk, &c. This may be examined in the railway-cuttings north of Hatfield, and in a pit on the hillside, east of the oil-mill south-west of Hertford. It can be traced all along the hillside from that to Hatfield; but there is no other good section here. Mr. Baker, of Bayfordbury, informed me that, in sinking a well at the east end of his house, they passed through 13 feet of springy gravel, 20 feet of dark-blue clay, and 10 feet of loose gravel and sand before they reached the chalk. These middle beds can be seen also

* See Geological-Survey Memoir on sheet 7, p. 22.

near Cole-Green Station, and in some good sections on the hillside south of the Mimram, near Tewin.

Boulder-clay sometimes, but rarely, occurs at the base of the gravels of the Lower or Valley-Plain. There is a small patch of reconstructed chalk and Boulder-clay resting on the chalk and covered by the gravel, in a road-cutting south of Broad Oak End Farm; and obscure sections, proving the same order of superposition, occur along the west side of the Beane, between that and Hertford.

Near Ware, we have a very peculiar development of these beds. Resting on the chalk (as seen south of Ware Park, and in the gravel-pits near Ware, and as found by sinking in the brickfields west of Ware), there is a varying thickness of sand and gravel, sometimes with large boulders. This gravel rises in a long bank, running west from Ware; and behind the bank, and on its north slope, there is a deep deposit of brick-earth, sometimes to 40 feet. This brick-earth is an even-bedded loam, sometimes finely laminated, like the Warp of the Humber, where the lamination is known to be due to tidal action. Some of the beds of loam are folded and crumpled up, and then covered by horizontal beds, in the manner generally ascribed to ice-action. On the top there are irregular patches of Boulder-clay and ferruginous subangular gravel: also near Hertford, in the brick-field near the Infirmary, there is a brick-earth in the Lower-Plain gravel; and in the large gravel-pit on the north side of the same hill there is a band of clay near the lower part, which seems to pass into a brick-earth at its east end. On the whole, it would appear that these brick-earths are local developments of the middle clays of the Lower Plain.

Some of these clays are very impervious to water; and therefore the gravel above them is stained red by the action of the surface-water, while that below preserves its buff or grey colour; but I have not found any constant characteristic by which we can distinguish the gravel above the clays from that below: in one section we find the coarser deposit above; in another it will be chiefly below.

I would refer the gravels of the Lower or Valley-Plain also to marine action—from the Boulder-clay in them, from the great extent of the middle clays, from the manner of occurrence of the banks of gravel, and from the estuarine character of the Ware brick-earths.

5. *River-Gravels.*—The deposits of the third period, or that of the present rivers, do not call for any detailed remarks in connexion with the points under consideration. They consist of the usual clays, brick-earths, subangular and mixed gravels, and may be examined along any of the rivers of the district, especially close to the railway-station at Kingsmead, near Hertford, and near the mill east of Hat-field Park.

6. *Summary.*—Thus we have in the neighbourhood of Hertford evidence of :—

1st. A plain of marine denudation of great antiquity, on which occurs a very marked pebble-gravel.

2nd. A period of emergence, during which great valleys were scooped out of that plain.

3rd. A period of submergence, when most of the old valley-deposits were re-sorted, and Boulder-clay deposited under, in, and on them.

This submergence went on until the Boulder-clay was dropped on the sides of the hills, and even on the top of the Higher Plain.

4th. A period of emergence, during which the present valleys were scooped out of the Lower Plain.

7. *Conclusion.*—The explanation I offer of the phenomena implies periods of submergence and emergence and periods of subaërial and fluviatile conditions so vast, that we may expect to find deposits of intermediate age, the record of various intermediate conditions.

Some such explanation must be given of the nearly obsolete terraces of gravel at the north end of Essenden Hill, some way above the Lower or Valley-Plain; also in Hatfield Park, south of the house; but I have no good evidence to offer as to their exact position in the series. Nor can I show where to place the pebble-gravel associated with brown clay in pipes and patches north of St. Albans. I do not think it can be referred to the Upper-Plain Gravel; but it may be the result of the subaërial waste of pebble-bearing Tertiaries &c. The manner in which the gravel and brown clay sometimes seem kneaded up together is curious, and can hardly be referred entirely to their sinking into pipes.

I do not offer this as an exhaustive sketch of the Posttertiary deposits of the neighbourhood of Hertford. All I mean to say is, that these are true natural divisions, which it is well to establish in a district where their relations to one another are more clearly seen, before any attempt be made to correlate them with similar deposits in other localities.

Postscript.—Since this paper was written, I have procured some mammalian bones from the gravels of the Lower Plain at Camps-Hill brickfield, near Hertford, some of which I saw in place. They are mostly in a very fragmentary condition; but Mr. Boyd Dawkins has referred them to Horse, Ox, Reindeer, Mammoth, and Tichorhine Rhinoceros. Through the kindness of Mr. Andrews, of the Camps-Hill brickfield, these are now in the Jermyn-Street Museum.

The section (fig. 2) shows the position of the bones.

Fig. 2.—*Section in Camps-Hill Brickfield.*

Scale, 8 feet to 1 inch.
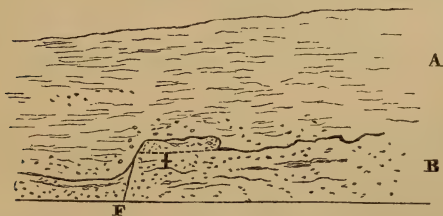
A. Newer brick-earth, a buff or yellow-brown loam, with about 18 inches of irregular fine flint-gravel in base.

B. Sand and loam, with Mammalian remains.   † Position of bones.

MARCH 11, 1868.

John Piggot, Esq., The Elms, Ulting, Maldon, Essex, was elected a Fellow.

The following communication was read :—

On the STRUCTURE *of the* CRAG-BEDS *of* NORFOLK *and* SUFFOLK, *with some observations on their* ORGANIC REMAINS.—Part I. CORAL-LINE CRAG. By JOSEPH PRESTWICH, Esq., F.R.S., F.G.S., &c.

[The publication of this paper is deferred.]

(Abstract.)

THE history of the division of the several crag-deposits into three formations (the Mammaliferous, Red, and Coralline Crags) having been recounted, the author states that for the last thirty years the evidence of their sequence has remained unaltered, the distinction between the Mammaliferous and Red Crags being still purely palæontological, not a single case of superposition having been discovered. Mr. Prestwich then proceeds to the special object of this paper, which is to describe more fully the physical structure of the several crags, and to determine, if possible, the exact relation which the Suffolk Crags bear to the Crag of Norfolk.

Commencing with the Coralline Crag, the author states that the well-known outlier at Sutton furnishes a base-line and the best clue to its structure and dimensions, showing also the depth to which it has been denuded and replaced by the Red Crag. The Coralline Crag is generally described as consisting of two divisions :—an upper one, formed chiefly of the remains of Bryozoa ; and a lower one, of light-coloured sands with a profusion of shells : and the author now gives their exact dimensions and his proposed subdivisions, as follows :—

CHARACTER AND THICKNESS.	LOCALITIES.
Upper Division, 36 ft.	
h. Sand and comminuted shells, 6 ft.	Sudbourne and Gedgrave.
g. Comminuted shells and remains of Bryozoa, forming a soft building-stone, 30 ft.	Sutton, Sudbourne, Gedgrave, Iken, Aldboro'.
Lower Division, 47 ft.	
f. Comminuted shells, with numerous entire small shells, 5 ft.	Sutton, Iken, Orford, High Gedgrave.
e. Sands with numerous Bryozoa, and some small shells and *Echini*, 12 ft.	Sutton, Broom Hill.
d. Comminuted shells, large, entire, and double shells, and bands of limestone, 15 ft.	Sutton, Broom Hill, Sudbourne.
c. Marly beds, with numerous well-preserved and double shells, 10 ft.	Sutton, Ramsholt.
b. Comminuted shells and Cetacean remains, 4 ft.	Sutton.
a. Phosphatic nodules and Mammalian remains, 1 ft.	Sutton.

Mr. Prestwich then states the localities at which these subdivisions of the Coralline Crag are exposed, and proceeds to discuss the

geographical distribution of the existing species in the several zones, and the present range of the organic remains. He agrees in the opinion that the greater number of the Mammalian remains are extraneous fossils; but regards those of a whale as truly contemporaneous, and probably also the teeth of the *Rhinoceros* and *Mastodon*, while the bones that are more or less drilled he considers to be derived. The occurrence of a large block of porphyry in the basement-bed at Sutton is considered a proof that a considerable degree of winter cold had been attained at that period, as it would be difficult to account for its presence in that bed except by ice-action; the author also enumerates the physical conditions which seem to be suggested by the mineral character and the structure of the several zones, inferring, from the peculiar mixture of southern forms of life with others of a more northern type, that at this early period the setting-in of conditions of considerable cold had commenced.

With the aid of Mr. Gwyn Jeffreys the author has revised the list of Mollusca from the Coralline Crag; and he gives a Table in which the range of the species in space, depth, and time is exhibited and an analysis of their synonymy by Mr. Jeffreys. He also discusses the relations of the Coralline Crag to its foreign equivalents, agreeing in the conclusion that the Crag Noir is a stage older than it, while the destruction of beds of the age of some of the older Crags of Belgium have furnished many of its derived fossils. In conclusion the author describes the distribution of sea and land at the period of the deposition of the Coralline Crag, as suggested by the affinities of the fossils of that deposit.

MARCH 25, 1868.

John Tyndall, LL.D., F.R.S., &c., Professor of Natural Philosophy in the Royal Institution and the Royal School of Mines; Allan Curr, Esq., Dora Terrace, Brixton Road; and Charles William Fothergill, Esq., Captain Royal Marine Artillery, Woolwich, were elected Fellows.

The following communications were read:—

1. *On some* NEW SPECIES *of* CRUSTACEA *from the* UPPER SILURIAN ROCKS *of* LANARKSHIRE &c.; *and further observations on the* STRUCTURE *of* PTERYGOTUS. By HENRY WOODWARD, Esq., F.G.S., F.Z.S., of the British Museum.

[PLATES IX. & X.]

AMONG the rich collection of fossil Crustacea from Logan Water, exhibited by Mr. Robert Slimon at the Meeting of the British Association at Dundee, in September last, were several new forms belonging to the order Merostomata, which have since been acquired by the British Museum.

I. The first new form is represented (Pl. IX. fig. 1) by (1) an almost entire individual, measuring 11 inches in length and 5 inches

in breadth, having one entire swimming-foot and three pairs of palpi *in situ*, and presenting the dorsal aspect of the body to view.

(2) I met with a second example of this species in the Museum of Practical Geology, Jermyn Street (see Pl. X. fig. 2). It consists of the anterior part of an individual about the same size as that first mentioned, exhibiting, *in situ*, the ventral aspect with the postoral plate or metastoma (*m*), the bases of the swimming-feet (*e, e*), three pairs of perfect palpi (*b, b*), and the basal joints of what may perhaps prove to be two anterior organs corresponding, in position, to the antennæ (*a, a*).

(3) I consider the detached organs and fragmentary remains figured on plates x., xi., and xiii. of Monograph I. of the Memoirs of the Geological Survey to be, in great part, referable to a species very closely allied to that from Logan Water.

(4) I am enabled to figure a very fine lip-plate, obligingly left for my examination some time since by Mr. J. W. Salter, F.G.S., which, like the remains figured in the Survey Monograph, was obtained from the Lower Ludlow rock, Leintwardine, Shropshire (see Pl. IX. fig. 2).

II. The second new form is represented (Pl. X. fig. 1) by the impression and counterpart of an entire specimen, measuring 2 inches in length and 1 inch in breadth, having all its appendages *in situ*.

That this may possibly be the young of some larger species I do not deny; but being quite distinct in general character from every form hitherto met with, I think it deserving description.

III. The third new species (Pl. IX. fig. 3) is at present known only by a single example, consisting of a head-shield and six mutilated segments.

The head is remarkable for its obtusely pointed triangular shape and prominent marginal eyes. It approaches somewhat in form to *Pterygotus Banksii* from the Lower Ludlow rock, but it cannot be referred to that species.

1. EURYPTERUS (PTERYGOTUS) PUNCTATUS, Salter, sp.

[Geol. Surv. Mon. I. 1859, p. 99, pl. x., pl. xi. figs. 5, 6, 7, 8, 9, 12, 13, 14 & 15, pl. xiii. figs. 5, 6, 9, 10, 11, 14.]

The characters by which the fragmentary remains associated together under this name have been distinguished are:—the form of the joints of the palpi, with their pairs of long, slender, recurved spines, and their well-marked basal joints (*coxognathites*); the form of the great swimming-feet, expanded in the penultimate joint, and attenuated at their extremities; the peculiar shield-shaped *metastoma* or postoral plate; and, lastly, the distinct punctate ornamentation which characterizes the surface of the body-segments and appendages.

Mr. Salter has attributed to this species a pair of long, slender, chelate antennæ; but I have no evidence in confirmation of this point, and, as these remains occur in the Lower Ludlow rock as *detached* fragments, their association with this species is, I venture to think, merely hypothetical.

As regards the form of the body-segments, Mr. Salter's evidence is most valuable in confirmation of the identity of these remains; for in the Survey Monograph he figures (p. 101) five of the anterior body-rings from Leintwardine, which agree closely in form with the specimen from Lanarkshire. He also observes (p. 99) that "the hinder segments were decidedly longer in proportion to their width than in *Pterygotus Anglicus*, or *Pt. gigas*." Indeed one of the segments which he has figured (Mon. pl. x. fig. 5) most clearly shows this to be the case.

From the evidence derived from the Lanarkshire specimens (described hereafter), I venture to refer this form to *Eurypterus*; it will probably come near Hall's *Eurypterus pachycheirus**.

But the specimens from the Lower Ludlow rock give evidence of a species *twice the size* of that occurring in Lanarkshire; there are also sufficient points of distinction in the form of the metastoma, the joints of the swimming-feet, the armature of the palpi, &c. to specifically distinguish them. I therefore propose to retain the name of *punctatus* for the Ludlow remains, as indicated, adding thereto (with a query) the great lip-plate here noticed for the first time (Pl. IX. fig. 2).

For the Lanarkshire specimens (Pl. IX. fig. 1, and Pl. X. fig. 2) I propose to adopt Mr. Salter's MS. name *scorpioides*, attached to the specimen in the Jermyn-Street Museum.

It is needless to enter here into a detailed description of the remains of this well-marked species—Mr. Salter having already done so, fully and ably, in the Monograph published by the Geological Survey, already referred to. I will merely mention such parts as are included in his description of this species, but which I see reason to exclude therefrom.

First, then, I would exclude the remains of the chelate antennæ —my reason for so doing being that all the species of Merostomata with spinous palpi have *small, simple antennules* (e. g. *Eurypterus, Stylonurus, Slimonia*).

Secondly, the lip-plate (Mem. Geol. Surv. Mon. I. pl. xi. fig. 4).

The form of the lip-plate is very characteristic of the separate divisions of this group; and I am not aware of any other species which possesses such a metastoma as is found in *E. scorpioides*, and which, from the detached plate now exhibited, I doubt not, also marked *E. punctatus*, the Leintwardine species. I would therefore suggest that the detached lip-plate (Geol. Surv. Mon. pl. xi. fig. 4) must have belonged to some other species—the form of the plate being more near that of *Slimonia acuminata*.

Thirdly, of the telson Mr. Salter observes that "it is yet wanting," and that "in all probability it was not unlike that figured on pl. x. fig. 11, which has possibly something to do with it."

On the fragment referred to, I will not venture to give an opinion, but will only observe that, as far as I can ascertain by a careful comparison, such a form would certainly have had an ensiform telson, as in the other *Eurypteri*, with which I venture to place it.

* And probably also near his subgenus *Dolichopterus*.

Form and dimensions of detached lip-plate (Pl. IX. fig. 2) referred to *E. punctatus* :—form, that of an armorial shield with its anterior corners truncated ; greatest anterior breadth 4 inches, length 5 inches ; sides curving inwards, and again expanding, then terminating posteriorly in a rounded margin only $1\frac{1}{2}$ inch in breadth.

2. EURYPTERUS SCORPIOIDES, sp. nov.   Pl. IX. fig. 1, & Pl. X. fig. 2.

Carapace semicircular in front, twice as broad as it is long.   Eyes not preserved, nor ocelli.

Organs of the mouth furnished with five (?) pairs of appendages, the first and most anterior pair imperfectly preserved (probably simple palpi as in *Slimonia, Stylonurus,* and certain species of *Eurypterus*).   Second, third, and fourth pairs 7-jointed, very robust; fifth, sixth, and seventh joints armed with a pair of strong recurved spines, the palpi and spines (in both specimens known) directed forwards ; fourth joint armed with several short incurved spines ; second and third joints without spines ; first joint serving as a *maxilla,* and armed with serrated teeth.   Length of palpi $3\frac{1}{2}$ inches, breadth at fourth joint $\frac{1}{2}$ inch.   Spines varying from $\frac{3}{4}$ to $1\frac{1}{4}$ inch in length, and 2 lines in breadth.

Swimming-feet or *maxillipedes* 7-jointed, $6\frac{1}{4}$ inches in length. Basal joint somewhat triangular in form, 14 lines long, 10 lines in breadth at posterior border ; maxillary border concealed beneath the metastoma ; breadth of articulation between the ectognath and second joint 8 lines, length of second joint 8 lines, of third joint 8 lines, of fourth joint 10 lines, of the fifth joint $1\frac{1}{2}$ inch, and breadth 10 lines ; sixth joint $1\frac{1}{2}$ inch long by 11 lines broad (a small triangular plate is inserted here as in *Slimonia* and *Eurypterus,* and probably also in *Pterygotus*) ; seventh joint $1\frac{3}{4}$ inch in length and 9 lines in breadth, with a minute nail 2 lines in length and $1\frac{1}{2}$ line in breadth, inserted at its distal extremity.

Lip-plate or *metastoma* shield-shaped, having its broadest border directed forward, 10 lines in breadth and the same in greatest length, anterior angles truncated, sides gradually converging towards the posterior border, which terminates in an obtuse angle.

Thoracic plate imperfect, but having a median appendage as in other species.   Surface punctate.

Body-segments.—First $\frac{1}{2}$ an inch long by 4 inches in breadth, curving upwards at the centre-line downwards on each side and upwards and inwards on its lateral borders.

Second segment 7 lines long in the centre by $4\frac{3}{4}$ inches in breadth, margin curved in a corresponding manner to the first segment, ornamented with two subcentral wart-like spots ; surface punctated.

Third segment 10 lines long in the centre, by $5\frac{1}{4}$ inches in breadth, ornamented in the same manner as the second segment.

Fourth segment 10 lines in length and $5\frac{1}{4}$ inches in breadth, border curved, marked subcentrally by two drop-shaped prominences $4\frac{1}{2}$ lines long.

Fifth segment 9 lines in length and $4\frac{1}{2}$ inches in breadth, ornamented as the fourth segment.

Sixth segment 8 lines in length, by $3\frac{3}{4}$ in breadth ; surface punctated.

Seventh segment 11 lines in length, by $2\frac{3}{4}$ in breadth, punctated as in the preceding.

Eighth segment 1 inch in length and $1\frac{3}{4}$ inch in breadth, punctated.

Ninth segment 10 lines in length and $1\frac{1}{2}$ inch in breadth.

Tenth segment 10 lines in length and $1\frac{1}{4}$ inch in breadth.

Eleventh segment 11 lines in length and $1\frac{1}{4}$ inch in breadth.

Twelfth segment 1 inch in length and 1 inch in breadth.

Telson wanting, probably ensiform as in other species of *Eurypterus*.

The punctate ornamentation (Pl. IX. fig. 16) is well seen on the anterior body-segments, and is at once readily to be distinguished from the scale-like markings seen on the body of *Pterygotus* and *Slimonia*.

3. EURYPTERUS OBESUS, sp. nov.   Pl. X. fig. 1.

This little form is remarkable for the great obesity of the thoracic somites, the breadth of the fourth segment being equal to the length of the first eight segments.

The carapace is 6 lines in breadth at its posterior border ; the lateral and anterior borders form a semicircle ; the length is 3 lines.

The surface of the carapace and segments was extremely thin, as shown by the puckered condition of the entire surface.   The dorsal surface, which is exposed to view, displays two eyes, placed $2\frac{1}{2}$ lines apart, and two subcentral ocelli.   Five pairs of appendages are preserved *in situ* :—

First, a pair of simple cylindrical antennæ (7 ?-jointed), 4 lines in length.

Second, third, and fourth pairs alike, and about 9 lines in length ; seventh joint unguiform.

Fifth pair of maxillipedes 1 inch in length ; third, fourth, and fifth joints small and somewhat narrow, sixth as broad as it is long ; seventh nearly oval, with small terminal talon, and united to the sixth joint by a small intercalated triangular plate.

Body-segments.—No ornamentation is visible on these, save a quadrilinear series of markings extending to the seventh segment[*]. First segment 6 lines in breadth and 1 line in length ; second segment 8 lines in breadth and 1 line in length ; third segment $9\frac{1}{2}$ lines in breadth and 1 line in length ; fourth segment 11 lines in breadth, by $1\frac{1}{4}$ line in length ; fifth segment 11 lines in breadth, by 2 lines in length ; sixth segment 11 lines in breadth, by $1\frac{3}{4}$ line in length ; seventh segment 10 lines in breadth, by $1\frac{1}{2}$ line in length ; eighth segment 7 lines in breadth, by 2 lines in length ; the border of this segment slopes rapidly inwards posteriorly, and is arched laterally ; ninth segment 3 lines in breadth and 2 lines in length ; tenth segment 3 lines in breadth and 2 lines in length ; eleventh segment $2\frac{1}{4}$ lines in breadth and $2\frac{1}{4}$ lines in length ; twelfth segment 2 lines

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[*] Bilinear markings are seen on the eighth and ninth segments.

in breadth and $2\frac{1}{2}$ lines in length; telson fragmentary, no doubt ensiform when properly preserved.

4. PTERYGOTUS RANICEPS, sp. nov.   Pl. IX. fig. 3.

Head-shield obtusely triangular. Eyes marginal. Breadth of posterior border of carapace 6 lines; greatest length $4\frac{1}{2}$ lines, from posterior border to eyes 3 lines; breadth of carapace at eyes $3\frac{1}{2}$ lines; diameter of eye 1 line. A small depression marks the centre of the carapace between the eyes; and a small elevation may be seen slightly posterior to them, also on the median line.

Length of six segments $7\frac{1}{2}$ lines, greatest breadth 9 lines; no ornamentation preserved.

No ocelli are visible; the eyes, however, are very prominent.

Further Observations on the Structure of Pterygotus.

In Messrs. Huxley and Salter's Monograph, already alluded to, there is figured on pl. 1. fig. 16, a portion of a *Pterygotus* (referred by Mr. Salter to *P. perornatus,* var. *plicatissimus*) exhibiting the squeezed and distorted carapace and anterior segments with the thoracic plate and its characteristic median lobe, "showing," says Mr. Salter, "what are perhaps the traces of the impressions of muscles for the ectognaths." The specimen is preserved in the Museum at Jermyn Street, where, by Professor Huxley's kindness, I have been permitted to examine it.

I have no doubt that we have here evidence of true branchiæ; and several other specimens which have since been obtained from Lanarkshire tend to confirm this view.

The specimens show a series of leaf-like bodies presenting a highly vascular and, at the same time, delicate structure, arranged in linear series of from six to eight in each row, and appearing to have occupied a position beneath the thoracic plate on the ventral surface of the body, as seen in *Limulus* at the present day (see Pl. X. figs. 3 *a* & 3 *b*). The form, however, of the branchial plates in *Pterygotus* is quite dissimilar to those in *Limulus*.

In the latter the vascular striæ are parallel to the circumference of the lamella of the gills; in the former they branch and subdivide from the centre to the margin of the plates, becoming finer and more numerous on the border.

Length of plates $1\frac{3}{4}$ inch long, by 9 lines in breadth.

Pterygotus bilobus, Salter *. This was formerly, and still continues to be, the most abundant species from Lanarkshire, and is frequently met with in a very perfect state of preservation.

It obtained its specific name on account of the bilobed character of the telson; but at that time no entire example of *Pterygotus perornatus* had been met with.

P. perornatus has now been obtained in a perfect state and is also furnished with a bilobed telson.

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* No figures are given here of the varieties of *Pterygotus bilobus*, as they will be delineated on the plates of the forthcoming number of the Palæontographical Society's Monograph on the Merostomata.
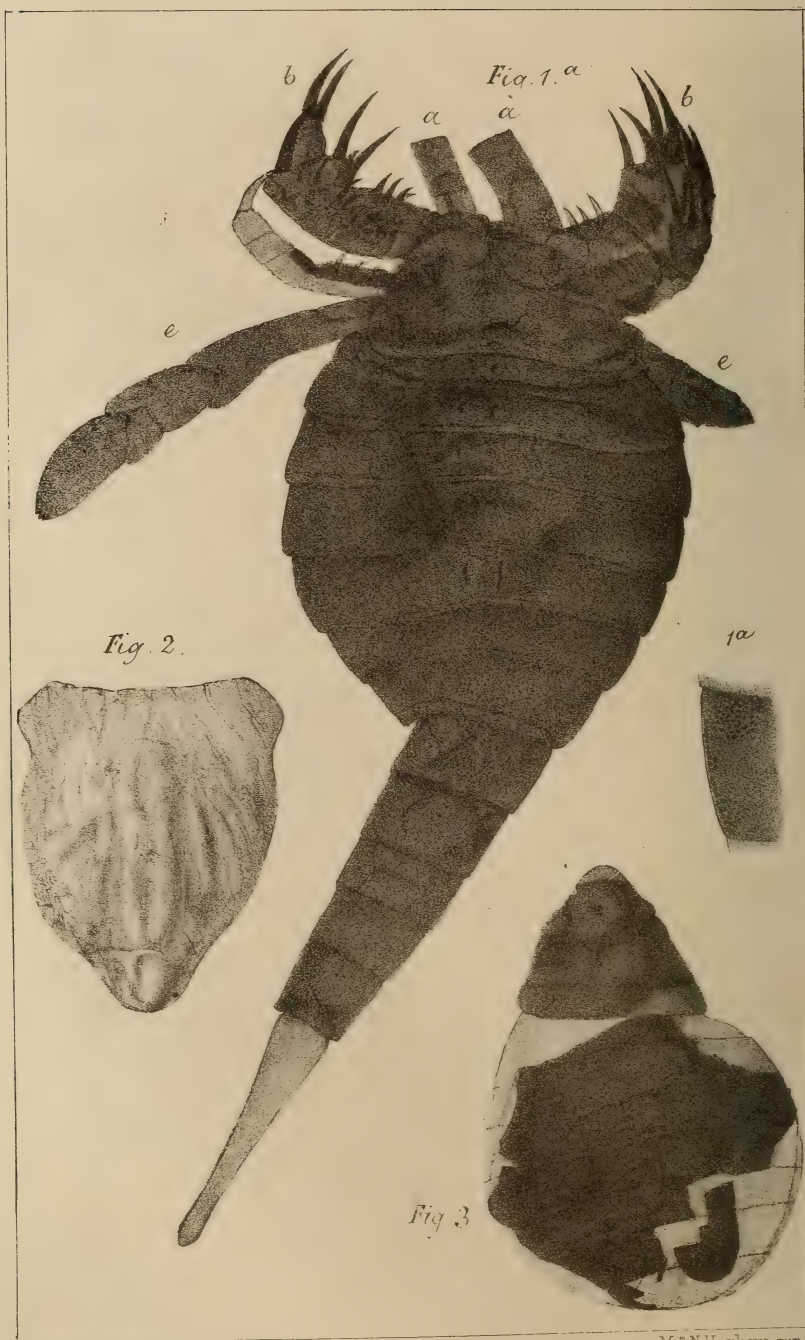
EURYPTERUS & PTERYGOTUS.

Fig 3.ᵇ

Fig. 1.

Fig.3.ᵃ

Fig. 2.

EURYPTERUS & PTERYGOTUS
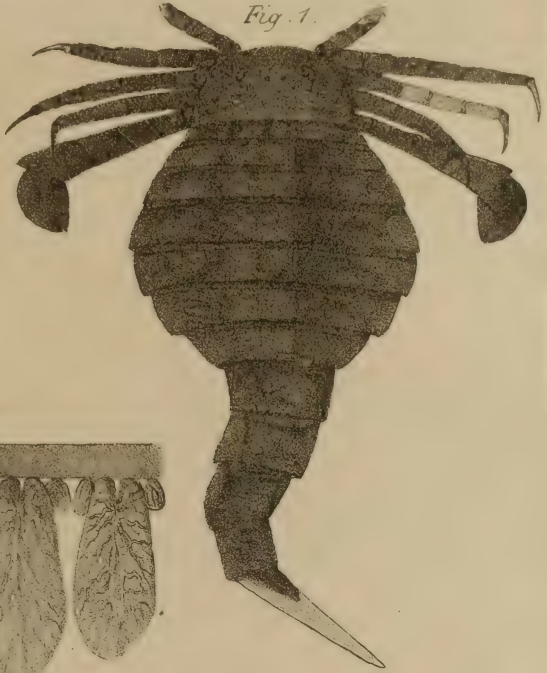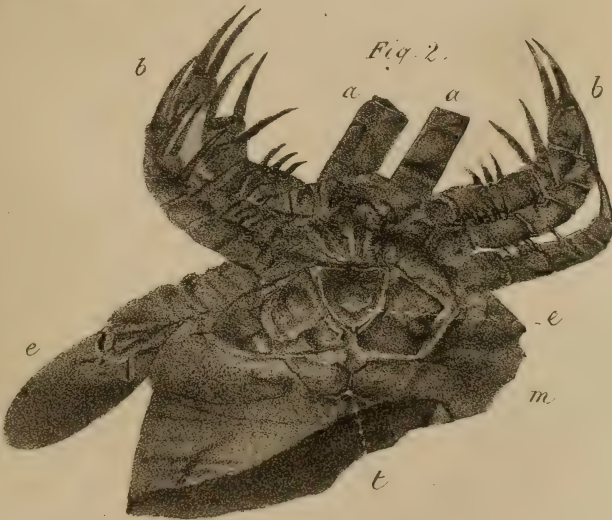
To add to the difficulty, a third form, readily separable from *Pterygotus bilobus* and *Pterygotus perornatus* by the greater breadth and narrowness of the thoracic segments in proportion to the succeeding abdominal ones, has been found, also possessing a bilobed telson.

I see no other way towards a solution of this difficulty, except by suggesting that the name *bilobus* be retained for all the three forms with bilobed non-acuminate telsons, treating them, for the present, as varieties only, until we obtain more positive evidence of their specific distinctness than we at present possess. The name *bilobus* may then be disused and the varietal appellation become of specific value. I propose, then, to term them thus:—

    α. *Pterygotus bilobus*, var. *inornatus*.
    β.   „   „   var. *perornatus*.
    γ.   „   „   var. *crassus*.

The following Table, giving the measurements of two specimens of each variety, will furnish an idea of the relative proportions of the three forms:—

	HEAD.				THORAX.				ABDOMEN.				TELSON.			
	Lat.		Long.		Lat.		Long.		Lat.		Long.		Lat.		Long.	
	in.	lin.	in.	lin.	in.	lin.	in.	lin.	in.	lin.	in.	lin.	in.	lin.	in.	lin.
Var. inornatus...	1	17	0	13	1	9	2	3	1	0	2	6	0	8	0	11
„ „ ...	1	16	0	12	1	9	1	4	1	0	2	0	0	7	0	11
„ perornatus .	3	0	0	22	3	9	4	0	2	0	4	6	0	17	1	9
„ „ ...	2	6	2	3	3	9	4	6	2	0	4	9				
„ crassus......	1	8	0	13	2	6	1	3	1	0	1	6	0	9	1	0
„ „ ...	2	0	1	6	2	6	1	6	1	3	2	3	0	13	1	3

N.B. The breadth given is the *greatest* breadth, and the length also at the *longest* point of the head, &c.

EXPLANATION OF PLATES IX. & X.

(Illustrative of Silurian Crustacea.)

PLATE IX.

Fig. 1*a*. *Eurypterus scorpioides*, Salter, MS. Nearly perfect specimen (two-fifths the natural size) from the Uppermost Ludlow Rock, Lesmahagow, Lanarkshire. This specimen exhibits the dorsal aspect. *a, a.* Imperfect antennæ. *b, b.* Palpi with long recurved spines. *e, e.* Ectognaths, or swimming-feet.

Fig. 1*b*. Portion of one of the thoracic segments, of the natural size, to show the punctate ornamentation.

Fig. 2. Metastoma or postoral plate referred to *Eurypterus punctatus*, Salter (one-third natural size), from the Lower Ludlow rock, Leintwardine, Shropshire.

Fig. 3. *Pterygotus raniceps*, H. Woodw. (twice the natural size), from the Uppermost Silurian, Lanarkshire.

    Drawn from specimens in the British Museum.

PLATE X.

Fig. 1. *Eurypterus obesus*, H. Woodw. (twice the natural size). Original specimen in the British Museum.

Fig. 2. *Eurypterus scorpioides*, Salter, MS. (ventral aspect), two-fifths the natural size. *a, a.* Basal joints of antennæ. *b, b.* Spinous palpi. *m.* Metastoma or postoral plate. *e, e.* Ectognaths, or swimming-feet. *t.* Part of thoracic plate. Original specimen in Museum of Practical Geology, Jermyn Street.

Fig. 3*a.* Supposed branchial plates of *Pterygotus bilobus,* var. *crassus,* H. Woodw. Natural size.

Fig. 3*b.* A single leaflet of the plates, drawn from a larger detached specimen. Original specimens in the British Museum. All from the Uppermost Silurian, Lanarkshire.

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2. *On the* CONISTON GROUP. By Professor R. HARKNESS, F.R.S., F.G.S., *and* H. A. NICHOLSON, D.Sc., M.B., F.G.S.

THE 'Quarterly Journal of the Geological Society' for 1865–66 (vol. xxii. p. 480) contains a memoir by the authors, entitled " Additional Observations on the Geology of the Lake-Country." In this memoir, after alluding to some new fossils from the Skiddaw-Slate group, and the occurrence of a fossiliferous ash-bed in the green slates and the porphyries in the Lake-country proper, the existence of several faults among the old rocks of this portion of England is indicated, and the total absence of strata containing characteristic Upper-Llandovery and Wenlock fossils is pointed out. The Kendal flags, the highest member of the Silurian series in the Lake-district, were also referred to as showing no distinct connexion with the older rocks lying to the north of them ; and it was stated that these Kendal flags are probably brought against the older members of the Silurian rocks by means of faults.

The object of the present communication is to point out the occurrence in the Lake-country of a new and unique horizon containing a rich Graptolite fauna in that portion of the Silurian series which has been termed by Prof. Sedgwick " the Coniston Flags," to describe in detail these flags, to point out their relations, both physically and palæontologically, with the Coniston limestone below them and the Coniston grits above them, and by this means to add a great thickness of strata to the highest member of the Lower Silurian rocks as this member is represented in the British isles.

The range of the Coniston limestone, the base of the series of rocks to which this communication refers, was described many years ago by Prof. Sedgwick, and also its position*.

This limestone, in its furthest extension in the eastern portion of the Lake-district, is seen at Shap Wells, being here immediately covered up by Old Red Sandstone on its eastern side. Westward from Shap Wells, for about two miles, the country is low and moory, and no further trace of this band of limestone is seen until Scale Head, a farmhouse a little south-west of Wastdale Crag, is reached. Here, in the course of a small brook, we have the limestone again appearing, but in a very different condition from that which it exhibits at all the other places where it can be recognized. At this spot it occurs in the form of a white semicrystalline limestone, having imbedded within it imperfect crystals of orthoclase, the form of

* Trans. Geol. Soc. 2nd series, vol. iv. p. 47 *et seq.*

felspar which is so abundant in the granite of Wastdale Crag.   At Scale Head the Coniston limestone is in very close proximity to the granite ; and its peculiar aspect doubtless results from the granitic influence: the granite itself, near the point of junction with the limestone, has also undergone considerable change, becoming fine-grained and compact, and losing those large imbedded crystals of felspar which are such a characteristic feature in the Wastdale-Crag granite.   Some portions even approximate to a felstone in their aspect and composition.

Section from below the Coniston Limestone to the Coniston Grits, inclusive.
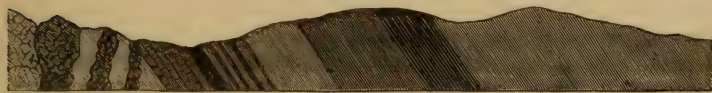
a. Coniston grits.	*e.* Graptolitiferous mudstones.	*h.* Ash-beds.
b. Sheerbate flags.	*f.* Trinucleus-shales.	*i.* Felstone.
c. Cleaved flags.	*g.* Coniston limestone.	*k.* Porphyry.
d. Grey grits.		

The country westward from Scale Head, for some distance, is moory, and the small brook-sections expose no Coniston limestone until a small stream flowing into the valley of Long Sleddale, called Arnco-side Beck, is reached *.

Although we have no exposures of Coniston limestone between Scale Head and this locality, the rocks that form the summits of the hills a little to the north of the strike of the line of the Coniston limestone are of a very interesting nature.

These rocks underlie the Coniston limestone, and they occupy the horizon of some of the ash-beds associated with the green slates and porphyries ; but in their mineral aspect they differ very greatly from the ordinary ash-beds, of which they are the representatives.   They are very compact, usually of a light flesh-colour, and are composed of almost pure felspar.   Their stratigraphical nature, however, is well marked, and the original lines of lamination are generally beautifully distinct.   They form a considerable portion of the summit of Harrop Pike, where they can be well seen ; and to the northward they pass downwards into the ordinary green slates and porphyries.   These rocks can, however, be traced further westward, and are seen near Little London, in the course of a small stream which here joins Arnco-side Beck from the north-east.   The latter locality affords some insight into the origin of these compact stratified felspars.   They are here covered by a mass of felstone resembling the portions of Wast-dale Crag, near where the granite comes in contact with the Coniston limestone ; and the influence of this felstone seems to have so far altered the felspathic ash-beds as to have converted them into a perfectly compact flesh-coloured rock.   The felstone can be seen both on the east and west side of Long Sleddale.   It is probably a

* In Prof. Sedgwick's Memoir this stream is called Iron Crow Gill.

portion of a great mass which at one time was connected with the granite of Wastdale Crag, the removed portion being very likely the agent which converted the green ash-beds into the compact felspar of Harrop Pike.

The strata which immediately overlie the Coniston limestone are not seen in the neighbourhood of Wastdale Crag, nor in the area to the south of Harrop Pike; but they make their appearance when the upper portion of Arnco-side Beck is reached. This small stream, which flows nearly along the strike of the strata, exposes the whole of the Coniston limestone, the ash-beds on which this limestone rests, and the rocks which succeed it, until the true Coniston flags are reached. The ash-beds, which underlie the Coniston limestone, are here somewhat earthy in their nature; they are regularly laminated; and between them and the Coniston limestone an ashy breccia is seen, composed of angular fragments of felspar cemented together by a green matrix. This ashy breccia is about two feet thick, and is intersected by felstone dykes, which also traverse the ash-beds and the lower portion of the Coniston limestone.

The Coniston limestone is here thin-bedded, and in its upper portion shaly. It is succeeded comformably by black mudstones which abound in Graptolites. These graptolitiferous mudstones pass up into grey grits, with beds of the latter interstratifying their upper portions. The grey grits contain few or no Graptolites, while in the interstratified dark-coloured rocks the same species occur which are seen in the more purely graptolitiferous mudstones.

The graptolitiferous mudstones do not extend upwards beyond the lower portion of the grey grits; and above them occurs a considerable and continuous thickness of the latter, which seems to be devoid of fossils. The grey grits are succeeded conformably by darker and more flaggy rocks in the form of the Coniston flags; and as soon as the latter are reached, Graptolites again make their appearance, two species, *G. priodon* and *G. sagittarius*, being by no means uncommon.

The strata, as seen in Arnco-side Beck, dip S.S.E. at about 40°.

Following the Coniston limestone on its line of strike, we find it exposed in Kentmere, the valley about a mile and a half west of Long Sleddale. Here the limestone has been wrought at Kentmere Hall; and the Coniston flags are also now extensively quarried a short distance to the south. There are, however, no sections in this valley showing the connexion between the limestone and the flags, the intervals being masked by superficial deposits. The same remark also applies to the vale of Troutbeck, where the Coniston flags have been very extensively worked, and where Graptolites are abundant along the lines of lamination, where the flags can be split parallel to the planes of bedding. The flags of Applethwaite Common, Troutbeck, are succeeded here by higher strata appertaining to the Coniston-flag series, to which Prof. Sedgwick has given the name "Sheerbate," but only from the circumstance that this upper portion of the Coniston-flag series splits parallel to the lines of bedding. The surfaces of some of these beds in Pennington's quarry afford

abundance of *Orthoceras primævum* and *O. subundalatum*, forms which range from the Caradoc or Bala rocks upwards to the Wenlock.

On the eastern side of Windermere, near Low Wood, in the course of a small stream flowing from Wansfell, and called Skelgill, a section is obtained similar to that of Arnco-side Beck, the Coniston limestone and the beds which support it being well seen here, and also the rocks succeeding the Coniston limestone. The course of this stream, like Arnco-side Beck, is nearly in the line of the strike of the strata; and immediately above the Coniston limestone the same black mudstones occur, with a profusion of Graptolites, similar to that of Arnco-side Beck.

Some portion of these graptolitiferous beds are highly anthracitic, and both here and at Arnco-side Beck the rocks have a great lithological resemblance to the graptoliferous shales of Dumfriesshire. These graptolitiferous mudstones also pass upwards into grey grits, as at Arnco-side Beck; but in Skelgill there are fewer shales interstratified in the lower parts of the grey grits. In Skelgill the Graptolites are often in relief, being in the state of iron pyrites, while in Arncoside Beck they occur usually as grey stains upon the mudstones.

At Skelgill by far the most abundant form is *Diplograpsus teretiusculus*, while at Arnco-side Beck no species can be said to be most predominant.

The following are the species of Graptolites which occur in the mudstone either in Long Sleddale or at Skelgill :—

1. Diplograpsus teretiusculus, *Hising*.	13. G. lobiferus, *M'Coy*.
2. D. angustifolius, *Hall*.	14. G. Nilssoni, *Barr*.
3. D. confertus, *Nich.*, n. s.	15. G. priodon, *Bronn*.
4. D. folium, *Hising*.	16. G. sagittarius, *Linn*.
5. D. palmeus, *Barr*.	17. G. Sedgwickii, *Portlock*.
6. D. putillus, *Hall*.	18. „ (var. triangulatus),
7. D. pristis, *Hising*.	*Harkness*.
8. D. tamariscus, *Nich.*, n. s.	19. G. tenuis, *Portlock?*
9. D. vesiculosus, *Nich.*, n. s.	20. G. turriculatus, *Barr*.
10. Graptolites Bohemicus, *Barr*.	21. Rastrites Linnæi, *Barr*.
11. G. discretus, *Nich.*, n. s.	22. R. peregrinus, *Barr*.
12. G. fimbriatus, *Nich.*, n. s.	23. Retiolites perlatus, *Nich.*, n. s.

—a very rich graptolite fauna, with which occur at Skelgill two Coniston-limestone fossils (*Sphæronites punctatus* and *Orthis calligramma*) and *Orthoceras primævum*?

Between Windermere and Coniston there are no exposures of the graptolitiferous mudstones, and there is an absence of sections showing them in the country south-west of Coniston—although the Coniston limestone and the harder rocks of the Coniston-flag series are well seen, especially west of the village of Torver.

The graptolitiferous mudstones being comparatively soft, their occurrence often gives rise to a narrow hollow immediately south-east of the Coniston-limestone band. Where this hollow is intersected by streams, gravel usually forms their beds, and the rocks on the sides are covered by soil. This is the case in Torver Beck, where the Coniston limestone is well exposed, and where the grey grits over-

lying the graptolitiferous mudstones are also well seen, but the intervening mudstones themselves are entirely hidden.

On the moor, on both sides of Torver Beck, the cleaved Coniston flags have been largely worked. They abound in Graptolites, which are well seen where the planes of bedding can be obtained; but cleavage renders this difficult, except in the weathered rubbish of the quarries. Besides *Graptolites priodon*, which is found in great abundance, a form possessing strong spines attached to the cell-mouth is seen, which appears to be *G. Sedgwickii*.

On Torver Moor the Sheerbate beds, which succeed the cleaved flags, are well seen, and have been worked. On the faces of these *G. priodon* occurs, but not in such abundance as in the cleaved beds. Associated with this is another species, apparently *G. colonus*, Barr. Besides these Graptolites, the higher strata of the Coniston flags yield other fossils*. The cleaved flags of Ireleth and Broughton Moor also afford *Retiolites Geinitzianus* †.

The Coniston grits, the succeeding member of this series, in the Lake-country are very barren in fossils. From these rocks, near Sedbergh, Mr. Hughes has obtained from the lower tough grits, principally from Helmside, near Dent, the following, viz. *Cliona, Spirorbis Lewisii, Ceratiocaris Murchisoni, C. robustus, Graptolites priodon, G.* sp., *Pterinea tenuistriata, Cardiola interrupta, Orthoceras Ludense, O. bullatum, O. angulatum*, and three other species; and from the higher sandy slates of the Coniston grits the following, viz. *Petraia, Encrinites, Ceratiocaris Murchisoni, C. robustus, Acidaspis* n. s., *Phacops, Graptolites, Pterinea tenuistriata, Cardiola interrupta, Lituites*, and *Orthoceras* three species ‡. Among the fossils which occur in the lower tough grits at Helmside is a Graptolite, *G. sagittarius*, a form not recognized as an Upper-Silurian species in any portion of the British Isles.

The palæontological relations of the Coniston limestone to the underlying green slates and porphyries have been already shown by the occurrence in these latter of ashy strata with well-marked Caradoc fossils §. The fossils which have been obtained from the Coniston limestone place this member of the group in, or very near to, the horizon of the Bala calcareous rocks.

In or above the Coniston limestone there are no traces of the ash-beds, or of the interbedded porphyries which are characteristic of the rocks which underlie the lowest member of the Coniston group. In the Bala country the same mode of occurrence seems also, to a great extent, to hold good, as few igneous rocks are met with above the horizon of the Bala limestone, the great igneous outbursts, so characteristic of the Caradoc rocks, having almost ceased before the period of deposition of this limestone. In some districts of the North of England the upper portion of the Coniston limestones are

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* Quart. Journ. Geol. Soc. 1866, vol. xxii. p. 483.

† This form is referred to *Diplograpsus pristis* in the Quart. Journ. Geol. Soc. 1866, p. 483. More perfect specimens have convinced us that this is a mistake.

‡ Geol. Mag. vol. iv. p. 356.   § *Tom. cit. suprà*, p. 482.

represented by calcareous shales; and in these latter are found very characteristic Caradoc fossils.

In the neighbourhood of Sedbergh, Mr. Hughes gives the following as occurring in these calcareous shales:—*Petraia subduplicata*, var. *crenulata*, *Encrinites*, *Phacops apiculatus*?, species of *Phacops*, *Trinucleus concentricus*, *Orthis biforata*, *O. calligramma*, *Strophomena depressa*, *S. alternata*, and species of *Orthoceras*.

The succeeding and conformable mudstones introduce an entirely new fauna, and one which has no representative in Great Britain among rocks appertaining to the Caradoc age. These rocks afford six species of the genus *Diplograpsus*, all of which, except *D. teretiusculus*, which has recently been obtained from the Caradoc rocks of Haverfordwest, are characteristic Upper Llandeilo forms.

Of the genus *Graptolites*, the species from these mudstones (with the exception of three, *G. Sedgwickii*, *G. priodon*, and *G. tenuis*, and the new forms) are also equally confined elsewhere in Great Britain to the Upper Llandeilo rocks; and another form, *Rastrites peregrinus*, also has hitherto been found in Britain only in the same horizon. Nearly the whole of the Graptolites, except the new species, of the mudstones above the Coniston limestone are of such forms as are most abundant in the black shales of Dumfriesshire.

Some of the species which are found in the Dumfriesshire shales have as yet not been met with in the mudstones; and the twin Graptolites, the *Didymograpsi*, which are represented in Dumfriesshire by several forms, seem to be entirely absent from the Coniston mudstones. The Upper-Llandeilo position of the Dumfriesshire graptolitiferous shales is marked by the occurrence of *Siphonotreta micula*; while, as regards fossil evidence, the Caradoc age of the mudstones is shown by the presence in them of *Sphæronites punctatus* and *Orthis calligramma*.

Although most of the Graptolites which have been obtained from the Coniston mudstones have previously been found in Great Britain in strata no higher than the Upper Llandeilo rocks, the case is somewhat different as regards Ireland. The Caradoc beds of Pomeroy yielded several of these species many years ago to the late General Portlock; and more recently the officers of the Irish Geological Survey have procured in other portions of Ireland, where strata of the Caradoc age occur, forms of Graptolites which are usually looked upon as marking the Llandeilo group. Two of these localities may be cited—one at Tramore, county Waterford, where, in black shale, underlying a calcareous flagstone with abundance of Caradoc fossils, the following species have been recognized by Mr. Baily, *Callograpsus elegans*, Hall, *Dendrograpsus flexuosus*, Hall, *Diplograpsus pristis*, *Didymograpsus sextans*, *Graptolites tenuis*, and *G. priodon**. The other is in the county Clare, where the following occur, *Didymograpsus Forchhammeri*, Geinitz, *D. hamatus*, Baily, *Diplograpsus pristis*, *D. mucronatus*, *Graptolites gracilis*, Hall, *G. Nilssoni*, *G.*

* Explanations to the sheets of the Irish Geol. Survey, No. 167, 168, 178, and 179, p. 20.

priodon, and *G. Sedgwickii*. Among the strata which are asso-
ciated with the graptolitic shales here, *Cardiola interrupta* is met
with, and it is found elsewhere in Ireland under similar circum-
stances*. Mr. Jukes, in a note appended to the account of this
occurrence of Upper Llandeilo and Caradoc fossils in the county
Waterford, notices this association, and seems disposed to refer it to
the recurrence of similar conditions and habitats at different Si-
lurian periods—a conclusion which the fossil evidence of the Conis-
ton mudstones appears strongly to support.

The occurrence of a rich Graptolite fauna among the Caradoc
rocks of Great Britain seems to have its parallel among the Silurian
rocks of Bohemia. Barrande places his rich Graptolite fauna towards
the top of the Lower Silurian, and among the base of the Upper
Silurian rocks; in the latter the graptolitiferous shales are associated
with traps.

The lower graptolitiferous series rests upon strata containing *Trinu-
clei*. In this occur five monoprionidian forms; and in the base of
the Upper Silurians there are twenty species, many of which are also
common to the Coniston mudstones. Of these the two diprionidian
species *D. palmeus* and *D. ovatum* (*D. folium*), and *Rastrites pere-
grinus*, are abundant among the Graptolites at Skelgill†.

In America, also, the richest Graptolite fauna, excepting that of
the Quebec group, seems to make its appearance in a series of rocks
which, in that country, in part represents the Caradoc formation.
These rocks are the Utica slates. They contain many of the forms
which are found in the Coniston mudstones, and they seem to be
very nearly on the same parallel with these latter rocks‡.

A circumstance of considerable interest in connexion with the
fauna and sequence of the Coniston group is the intercalation of the
mudstones and their fossils with the grey sandstones which lead up
into the cleaved Coniston flags. The occurrence also of *G. sagitta-
rius* in so high an horizon as the Coniston grits connects these latter
with the rest of the Coniston series.

There are other fossils which are common alike to the Coniston
flags and Coniston grits; but in the grits forms make their appear-
ance which have not hitherto been discovered elsewhere. The fossils
of these grits have very little affinity with those of the Kendal
flags, nor do they exhibit such a facies as would connect them with the
lower members of the Upper Silurian series. Palæontologically,
therefore, this Coniston series of the north-west of England must
be looked upon as a continuous group of rocks extending from, and
including, the green slates and porphyries to the top of the Coniston
grits.

The physical evidence also leads to the same conclusion. Every-
where, as was long ago pointed out by Prof. Sedgwick, there is the
same sequence; there is no overlap, but there is a perfect conforma-
bility throughout the whole series.

Under such circumstances we have in the Lake-district a greater thickness of rocks conformably above the representative of the Bala limestone than is to be found elsewhere in the British islands. If we adopt the measurement of Mr. M‘Kenny Hughes for these rocks as they occur near Sedbergh, we shall have a thickness, exclusive of the calcareous shales at the top of the Coniston limestone, of upwards of 7500 feet, made up of slates (mudstones) some hundred feet, tough grits 1000 feet, Coniston flags 2000 feet, Lower Coniston grits 1200 feet, and Upper Coniston grits 3000 feet[*]. This gives us a thickness of strata considerably exceeding the whole of the Upper Silurian rocks of Wales.

Some of the members of this series in the Lake-country proper are not so thick as those in the area where Mr. Hughes's observations were made. This is the case with the graptolitiferous mudstones. Others, however, as the Coniston flags, are probably somewhat thicker; and on the whole it is not likely that there is any great difference in thickness between the two areas. We require, therefore, now to add to what has hitherto been regarded as the Caradoc or Bala formation, a great thickness of strata which contain in their higher parts some new forms of life, but which on the whole possess a decidedly Lower Silurian fauna.

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3. *On the* DEATH *of* FISHES *on the* COAST *of the* BAY *of* FUNDY. By A. LEITH ADAMS, F.G.S., Surgeon, 22nd Regiment.

WHEN engaged in a shooting-expedition in the forests of Southwestern New Brunswick at the entrance of the Magaguadavic River, I had my attention directed to an extraordinary occurrence which took place on the 24th of September, 1867, in one of the numerous inlets or creeks in the Devonian and Silurian beds that constitute the chief geological formations of this portion of the coast-line of the Bay of Fundy. Anderson's Cove, as it is called, is a small bay to the west of the mouth of the above-named river, and at the entrance of a valley, down which runs an insignificant stream emptying into a muddy lagoon about 1200 feet in circumference at high water. This lagoon is oval-shaped, the small end communicating with Anderson's Cove by means of a narrow and rocky channel at its eastern extremity. A sea-wall, formed of rocks, stranded logs, and lumber piled in confused masses, intervenes between the cove and the lagoon in front; so that the only direct communication is by the passage just mentioned. The area thus enclosed forms a large lake at high tide, into which the waves rush and retire with great force, whilst at ebb tide the water is shallow, forming a muddy morass of about half the dimensions already given. On the 24th of September, during a heavy gale from the west, impinging almost straight on the entrance to the lagoon, and whilst the sea was running high, enormous numbers of small fishes were observed floating dead on the surface of the lagoon, and being thrown up in quantities by the waves; and on

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[*] *Op. cit. suprà*, p. 335.

the gale subsiding, a spectacle presented itself on the following morning unparalleled by anything of the kind ever witnessed by the present settlers. The whole surface of the lagoon and its banks, from the entrance to the limits of high tide, was covered with dead fish, to a depth of a foot in some places, whilst a few disabled individuals were seen swimming in the lagoon or making their way back with the returning tide. With the exception of a few Mackerel and New-York Flounder (*Platessa plana*), this vast host belonged to one species, the *Clupea elongata*, or American Herring, and averaged about 6 inches in length. The Herring is said to spawn in this neighbourhood; at all events large quantities are captured by torchlight and nets, chiefly to form a patent manure, which is manufactured at Eastport. Both before and for some days subsequent to the 24th of September, large shoals were noticed along the coast, and many barrelfuls of herrings were caught at the mouth of the river. Some idea of the vast numbers congregated in the lagoon on the occasion in question may be drawn from the fact that there was not a farmer within a circuit of five miles who did not carry off several cartloads for manure, so that a large portion disappeared before my arrival on the 8th of October; nevertheless the offensive smell was experienced at a distance of two miles, and the air of the surrounding country was contaminated also from the quantities strewn on the fields by the farmers. On our arrival at the scene, the smell became sickening; the whole surface of the lagoon and its banks were literally covered with decomposing fish, on which the Kittiwake, Buffon's Squa, and other gulls, with crows, were feeding sumptuously. It became clear that the shoal had been impelled by the force of the waves on the coast, and were dashed to death against the cliffs; for the fallen masses of rock in the passage to the lagoon were thickly besmeared with herrings crushed as if they had been pounded in a mortar, whilst the muddy bottom and alluvial bank of the lagoon were absolutely paved with their dead bodies, in spite of the enormous quantities removed previously by the settlers. By some fishermen it was surmised that the shoal had been driven ashore by sharks or other predaceous fishes; but the presence of a severe gale at the time, a land-locked bay, and the fury of the waves on such a vast mass of fish, once fairly within their influence, indicate that their destruction was the result of mere accident. When once the shoal of fishes got into shallow water (as a matter of course at the entire mercy of an unusually boisterous sea), it seems to me that there was no escape, and that their total destruction was inevitable.

Such incidents as the above seem exceedingly rare, at least as far as this portion of America is concerned; I notice, however, a similar occurrence recorded in the Proceedings of this Society as having taken place on the coast of India.*

To the geologist, it is needless to remark, such accidents as the above cannot be otherwise than intensely suggestive. Here we have

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* " On the Death of Fishes during the Monsoon off the Coast of India," by Sir W. Denison, read June 18, 1862.   Quart. Journ. Geol. Soc. vol. xviii. p. 453.

the Devonian and earlier Palæozoic rocks covered with Glacial drift, now being overspread by a marine deposit in which enormous quantities of one species of fish, in every possible state of integrity and mutilation, are mixed up with Mussels and other recent shells, Crustacea of large dimensions, tests of Echini and other Radiata, Annelids, Plants, &c. &c. The majestic tidal wave, as it rushes up the Bay of Fundy, will soon cover up these remains ; and in the far distant future mayhap some geologist may speculate on the causes that brought about this wholesale destruction of so many fish, just as we are lost in wonder and astonishment how and by what manner of means suchlike phenomena took place in many instances among the Devonian and Carboniferous systems of this and other continents.

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4. *On* VOLCANOES *in the* NEW HEBRIDES *and* BANKS'S ISLANDS. By the Rev. JOSEPH ATKIN, of the Melanesian Mission, Norfolk Island.

[Communicated by T. Codrington, Esq., F.G.S.]

(Abridged.)

BETWEEN 166° and 170° east long., and the parallels of 13° and 21° south lat., is the chain of volcanic islands called the New Hebrides. The Banks's are another small group to the north, and the Torres are five low islands to the north-west. Of the New Hebrides, Tanna, Lopevi and Ambrym are now active volcanoes; of the Banks's Islands, Santa Maria and Great Banks's Island.

At Great Banks's Island there are boiling springs, and a great number of little vents discharging hot sulphureous vapour. At Santa Maria there is only one of these. A great part of the interior of the large island of Ambrym seems perfectly bare of vegetation. The present volcanic action is on the east slope. No crater can be seen, but all the active eruption is in a part two or three miles in extent. It seems to be constant, and violently active. There does not seem to have been any lava-stream recently ; but the whole western coast of the island is formed of large irregular masses of lava. There is a fringing reef of coral on the eastern side of Santa Maria, and a short one at the north end of Ambrym.

The Island of Lopevi is not more than two miles and a half long, and is upwards of 5000* feet high ; from some points it appears as a perfect cone. It was not known to be active until 1863, when its peak, formerly quite sharp, appeared to have been broken off, and a thin volume of smoke was going up from the top. The trees, too, appeared to have been killed in divergent lines running down from the top of the mountain. In 1864 it was very active ; in working past it at night we had a fine view of it flames ; shooting up from the crater lighted up all the top of the mountain almost every minute ; and once the lip of the crater broke away, and an avalanche of hot stones and ashes ran down like a stream of fire to the sea. On pulling to the shore on the lee side, we saw no lava ; but very fine

* Measured by Mr. Tilly, Master, R.N., of the 'Southern Cross.'

ashes, strewn to the depth of several feet down the mountain-side, had killed all the trees and shrubs near the top, and even near the sea ; nothing was living in places but the *Casuarina*, with its leaves scorched white. There is no coral to be seen about this island.

Tanna I have only seen from a distance : the flames going up from it can be seen a very long way at night ; but I do not think it is so violent as Ambrym. The little Island of Paama, near Lopevi, has a coral patch to the south-west of it, but has no coral rocks out of water. Lepers' Island has one or two shoals, with coral on them ; but appears to be altogether volcanic. Star Island has no coral cliffs, and, as far as I know, no shoals ; it goes down steep to the sea, and has deep water close to the rocks. There is no water at Lepers' Island, except what is filtered into little pools in the sand from the sea. At Mera Lava (Star Island) there is always water in the crater, but, except just after rain, no other but that obtained as at Lepers' Island.

Vanna Lava (Great Banks's Island) is the largest island of the Banks's group. It has seven rounded hills, irregularly forming the letter S. The upper or northern and central hills are joined by low land ; the bases of all run into one another at a height of from 400 to 800 feet above the sea-level. There are no craters visible, except the active one ; its hill is more pointed than the rest ; all, however, seem to be volcanic.

On the 13th of July we set out to see the " ours," as the natives call the hot springs. After a walk of some hours we crossed a brook rushing down amongst huge boulders coated with a white deposit. The water was lukewarm, whitish, and sent up a creamy-looking acid vapour. Suddenly we came to the top of a ridge, and going down a very steep path found a small stream of warm water, smelling of sulphuretted hydrogen. We saw that a few hundred yards further up the stream smoke was coming out of the opposite bank ; but we went on, up through some scrub, until we came to an open space of about an acre with little funnels all over it, throwing off fumes of sulphur ; the larger ones had raised tumuli of sulphur round them. In one hollow these were quite thick together and sent up a light smoke, which we can usually see from our anchorage, six miles distant in a straight line. About half-an-hour's walk brought us to another of these places, much smaller, but with hotter fires than the lower one. The natives, knocking off the top of one of the sulphur heaps with their sticks, made a little eruption ; the lumps that fell down the chimney were thrown up into the air, knocking away more of the top of the heap, and scattering it in all directions. We crossed a little stream, but came upon it again higher up, and walked up its bed to the springs. The water was milky-looking, semitransparent, without any particularly offensive smell. It was just as hot as we could bear. The source of this stream is a pool or small lake about fifty yards long. At the end nearest the outlet it boils up with what must be nearly cold water, for it gives out no steam. At the other end the banks rise and narrow the lake into a little gorge ; the end of it is hidden by a constant jet of steam 5 or 6 feet in diameter,

very dense, and rising with scarcely any noise, but very fast, up the almost perpendicular face of the hill, which rises to the height of 600 or 700 feet behind it. By a short circuit we got to the top of this cliff and could look down into the lake, but we saw only the windward half of it; underneath us was solid-looking steam, rising up to where we were standing. As seen from above, the lake looks like the bottom of a large crater two or three miles across, with high hills on three sides, but having the windward side (the south-east) open. There was no appearance of any old craters beside this; but all the eastern side of the hill that forms the northern boundary of the crater is full of little vents, which sometimes can all be seen smoking, but commonly only a few small puffs are visible from the sea. Three years since, flames were seen apparently rising from the place; and eight years since, the mountain was very active: large quantities of ashes fell at Mota, ten miles to windward, withering the leaves of some of the trees there. When we stood by the lake, we felt a slight trembling of the earth, but only when very near to it.

April 8, 1868.

W. F. Webb, Esq., Newstead Abbey, Notts; The Rev. H. W. Crosskey, 10 Corunna Terrace, Glasgow; G. H. West, Esq., B.A., Christchurch, Oxford: T. Ainstie, Esq., B.A., C.E., Devizes; R. H. Brunton, Esq., C.E., 84 George Street, Edinburgh; and H. B. Woodward, Esq., of the Geological Survey of England, were elected Fellows of the Society.

The following communications were read:—

1. *On the* Affinities *and* probable Habits *of the extinct* Australian Marsupial, **Thylacoleo carnifex**, *Owen.* By William Henry Flower, F.R.C.S., F.G.S., F.R.S., &c., Conservator of the Museum of the Royal College of Surgeons.

The late Dr. Falconer, in a paper published in the Quarterly Journal of this Society for November 1862[*], has given a masterly and detailed statement of the arguments which led him to infer that the small oolitic mammal, *Plagiaulax*, known only by its lower jaw, was a phytophagous or mixed-feeding animal, having its nearest allies among the recent *Hypsiprymni*, or Rat-kangaroos. This paper was written in consequence of Professor Owen having published his conclusion, from precisely the same data, that *Plagiaulax* was a " carnivorous marsupial," its teeth being fitted to " pierce, retain, and kill," and "cut and divide soft substances such as flesh."

As justly stated by Dr. Falconer, the interests involved in the case are important. " Are the indications of palæontology," he inquires, " more especially in its great stronghold in the mammalia— the teeth and correlated organs—so unstable and so obscure that, of two palæontologists, the same dental and mandibular materials shall lead the one to infer that the fossil form was a vegetable

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[*] Quart. Journ. Geol. Soc. vol. xviii. pp. 348–369.

feeder, and the other that it was a predaceous carnivore? Or does the conflict of opinion arise from different methods having been followed by the observers in dealing with the evidence?" He concludes that the question will not rest in its present disputed state. " Other palæontologists will examine the evidence, and give their verdict."

For my part, I cannot hesitate to express my full conviction of the soundness of Dr. Falconer's views, as far as may be deduced from the evidence before us. There is one point, however, referred to incidentally but frequently in the course of his paper, on which I am obliged to differ from that distinguished palæontologist, without in the slightest degree wishing to impugn his well-known and justly esteemed acumen and discernment in such matters ; for it is a point on which he had evidently never concentrated those powers of mind which led him to so logical a conclusion in the closely reasoned case of *Plagiaulax.*

This animal had been associated by Professor Owen with *Thylacoleo,* " a much larger extinct predaceous marsupial from Tertiary beds in Australia "*. Dr. Falconer, in his anxiety to show that *Plagiaulax* could not have been carnivorous, has endeavoured to separate it as much as possible from *Thylacoleo,* laying great emphasis on all the points of divergence that could be found between them. He was evidently under the impression that the latter had been proved to be a carnivorous marsupial, without staying to inquire into the arguments on which the assumption rested—the real fact, however, being, as I shall endeavour to show, that the affinities of *Plagiaulax* and *Thylacoleo,* correctly discerned by Professor Owen, tend rather to strengthen, instead of detracting from, Dr. Falconer's main argument.

The history of the last-named remarkable animal is as follows : —In a paper in the Philosophical Transactions for 1859 (p. 309), under the title " Description of a mutilated skull of a large Marsupial Carnivore (*Thylacoleo carnifex,* Owen) from a calcareous conglomerate stratum, eighty miles S.W. of Melbourne, Victoria," Professor Owen gave a detailed and illustrated description of a specimen, discovered by Mr. W. Adeney, and presented, in 1846, to the Museum of the Royal College of Surgeons, by Dr. Hobson, of Melbourne, proving beyond question its marsupial character, and stating that " the chief conclusion as to the affinities of the animal to which they the [fossil remains] belonged had been indicated by the term *Thylacoleo, i. e.* Marsupial or Pouched Lion," and that "amongst existing *Marsupialia* the *Sarcophilus,* or *Dasyurus ursinus* —at present the largest existing species of its genus—seems to me to have the nearest affinities to the *Thylacoleo,* although the interval be still very great between them." It was further stated in this paper, " From the size and form of the carnassials of *Thylacoleo,* especially the upper one, we may infer that it was one of the fellest and most destructive of predatory beasts."

In a later volume of the Philosophical Transactions (1866, p. 73),

* Owen, 'Palæontology,' 2nd edit. p. 354 (1861).

Professor Owen described and figured a more complete skull, belonging to " the same large carnivorous marsupial." The specimen was obtained from " that part of the freshwater deposits of Darling Downs through which the river Condamine has cut its bed." The additional evidence afforded by the more perfect condition of the specimen appears to have modified Professor Owen's views as to the affinities, though not as to the diet and habits, of the animal. " *Thylacoleo*," we now read, " exemplifies the simplest and most effective dental machinery for predatory life and carnivorous diet known in the mammalian class. It is the extreme modification, to this end, of the Diprotodont type of *Marsupialia*. Besides the full confirmation which the additional fossils here described give of the marsupiality of *Thylacoleo*, its closer affinities in that order are shown to be, not to the existing carnivorous marsupials, *e. g. Sarcophilus*, *Dasyurus*, *Thylacinus*, *Didelphys*, but to the Diprotodons, Nototheres, Koalas, Phalangers, and Kangaroos."

Beyond this incomplete cranium and mandible, nothing is at present known with certainty of the structure of this remarkable animal *. But from the information contained in the above-quoted memoirs, with some additional observations derived from the examination of some more recently received fragments in the British Museum, and part of a mandible (from the Wellington Valley) in the Museum of the College of Surgeons, the dental characters are sufficiently apparent to enable us to draw with tolerable certainty all such conclusions as to affinity, food, and general mode of life as may legitimately be derived from the study of this most important part of its organization.

The first subject upon which the attention will naturally be engaged when any new object of this nature is brought to light is a comparison with already known forms, with a view to ascertain to which of them it most nearly approximates. This inquiry must precede any purely deductive speculations as to its characters or purpose.

The most striking feature in the dentition of *Thylacoleo* (see fig. 1, p. 312) is the single huge compressed trenchant premolar† tooth in either jaw. This tooth alone, interpreted by a mere empirical comparison with teeth of known animals, appears sufficient to furnish the key to the whole question at issue. Professor Owen, naturally pursuing this method of proceeding, fixed upon the so-called " sectorial," or " carnassial " tooth of the Lion as its nearest similitude among mammalian teeth, and has ever since spoken of it as a " sectorial " or " carnassial," and assigned corresponding functions to all the other teeth. It was the examination of this same tooth, resulting in finding that it agreed more closely with a tooth of a very different animal, that has lead me to another conclusion.

That the resemblance of the great premolar of *Thylacoleo* to the

* That the metacarpal bone figured in the Phil. Trans. 1859, pl. xiii. belonged to the same animal as the skull, is only conjectural.

† So called from its apparent homology with the posterior premolar of the recent marsupials.

" carnassial" of the true Carnivora is merely superficial is easily shown. Indeed the differences between the upper tooth, with its simple crown and " even and uniform " trenchant edge " describing a very feeble concavity lengthwise," and the trilobed crown of the Feline carnassial, and especially the absence of any distinct inner lobe or tubercle supported by a third fang, have been so clearly pointed out in the original description (Phil. Trans. 1859, p. 311) that little more need be said on this point. There is another striking difference in the lower tooth from that of the true Carnivora. As is well seen in the jaw in the Museum of the Royal College of Surgeons, in which the tooth is broken off rather below the base of the crown, it has two roots, of which the anterior is considerably smaller than the posterior, whereas in the lower sectorial tooth of the cats and hyænas, these proportions are always exactly reversed.

The differences which exist between these teeth of *Thylacoleo* and their supposed representatives in the implacental carnivora are still greater. Indeed there is no tooth, either of the upper or lower jaw, of any of the Thylacines, Dasyures, or Opossums that can be with any reason compared with them. When, however, we pass to another group of the same subclass, the *Hypsiprymni* or Rat-kangaroos (fig. 2, p. 312), we see at once in the great cutting premolar a miniature of that of *Thylacoleo*. The position in the jaws, the shutting of the upper tooth against the outer edge of the lower one, as shown by the wearing and polishing of the respective surfaces, the general character of the simple, compressed, trenchant crown, without any accessory cusps or tubercles, and the relative proportions of the anterior and posterior fangs of the lower teeth precisely correspond.

On comparing a large series of skulls of *Hypsiprymni* of different species it will be found that this tooth, though always retaining the above general characters, varies greatly in the details of its configuration and in relative size. In some species it is much larger in proportion to the size of the skull and the other teeth than in others. In some the internal and external surfaces are nearly flat, in others concave. The free margin in some is nearly straight, in others (and this is more often the case) more or less concave. Lastly, the vertical grooves and ridges on the sides of the crown, found in nearly all, vary greatly in number and character, being numerous, fine, regularly parallel, deeply cut, and closely placed in some, as *H. Gaimardii* and *H. Grayii*, or few in number and almost obsolete, as in *H. campestris, murinus*, and *rufescens*. Among all these modifications the corresponding tooth of *Thylacoleo* would easily find a place, although it agrees exactly with no one existing species. The vertical grooves and ridges, though distinct enough to show its adherence to the type, are as little marked as in some of the existing species mentioned above. In relative size it considerably exceeds even that of *H. rufescens* or *Dorcopsis Mülleri*.

To pass to the other teeth of *Thylacoleo*, the incisors in the upper jaw are three on each side, known only by their sockets and the broken stump of the first, which was clearly much larger than the other two ; below there was a single large compressed inci-

sor close to the middle line, directed obliquely upwards and forwards. In the number and arrangement of these teeth, therefore, *Thylacoleo* corresponds exactly with the modern families *Macropodidæ* and *Phalangistidæ*, and differs completely from the carnivorous marsupials. The same may be said of the canines, which are entirely absent in the lower jaw, and represented above by a very small, simple, conical tooth (fig. 1, *c*), exactly as in the *Phalangistidæ* and the greater number of *Macroprodidæ*, especially *Hypsiprymnus* (fig. 2, *c*). Between the canine in the upper jaw, and the great trenchant premolar, there are moreover two small simple teeth, with rounded crowns, which must be regarded as anterior premolars. In the presence of these teeth *Thylacoleo* differs from *Hypsiprymnus* and all the *Macropodidæ*; but in *Phalangista* one or more of such small teeth in front of the large posterior premolar (undoubtedly homologous with the great premolar of *Hypsiprymnus* and therefore probably with that of *Thylacoleo*) are the rule.

One of the most remarkable features in the dentition of this animal is the reduction in number and size of the true molars, of which but one is present in the upper, and two in the lower jaw. This reduction is evidently in relation with the excessive development of the great trenchant premolar. It is interesting to observe a tendency to the same occurrence in the recent allied forms. While in the true Kangaroos, where the premolar is relatively small, the true molars increase in size from the first to the fourth, in all the Rat-kangaroos, on the contrary, they decrease, and the last is always notably smaller than the others. In many species this is quite rudimentary; and it is occasionally altogether absent on one or both sides, reducing the number of true molars to three, as in specimens of *H. Ogilbyi* in the British Museum. The form of the molars differs greatly in different members of the *Macropodidæ*; but these teeth in *Thylacoleo*, in their rudimentary and stunted condition, offer no characters by which they can be compared very closely with any of the known forms.

There is nothing, in the structure of such portions of the cranium and mandible of *Thylacoleo* as are known, which belies the conclusions arrived at as to its affinities from the dentition. It differs much from any of the now existing *Macropodidæ* in the small relative size of the brain-cavity, and in the great development of the temporal ridges, which meet in the middle line at the top of the skull, forming a sagittal crest. This is probably only a difference of the kind always observable in comparing large with small species of a natural group, and not an indication of its affinity with the smaller-brained carnivorous Dasyures and Opossums. In the phytophagous Phalangers, moreover, the sagittal crest is as strongly developed, and the brain-case almost as small as in *Thylacoleo*.

In the conspicuous development of the postorbital processes it differs from nearly all the members of the two families to which otherwise it appears most closely related; but some *Hypsiprymni*, as *H. murinus*, have such processes well marked; and their unimportance as a family character is shown in the Wombats, where they

Fig. 1.—Thylacoleo carnifex, *restored*.   *One-third the natural size.*
*From specimens in the British Museum and Museum of the Royal
College of Surgeons.*
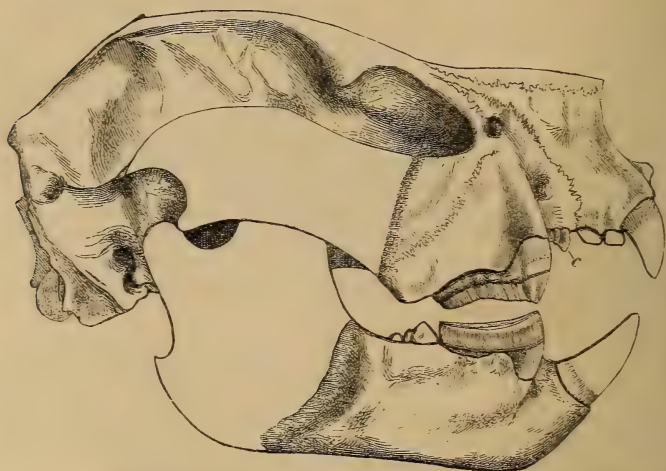
The unshaded parts are conjectural. *c.* The canine. The small upper tuber-
cular molar is concealed behind the large compressed trenchant premolar.
The cutting edges of the premolars, especially of the lower one, are much
worn.

Fig. 2.—Thylacoleo carnifex, *restored*.   *One-third the natural size.*
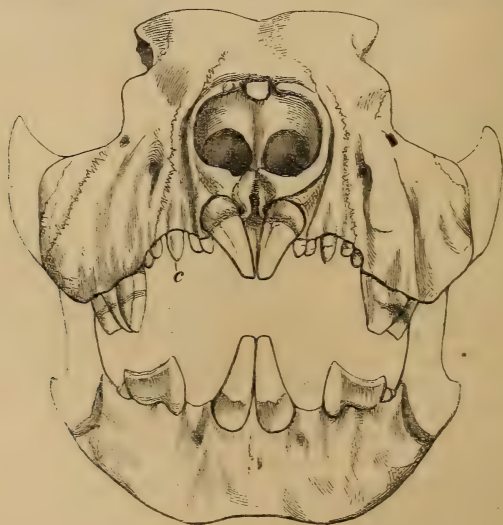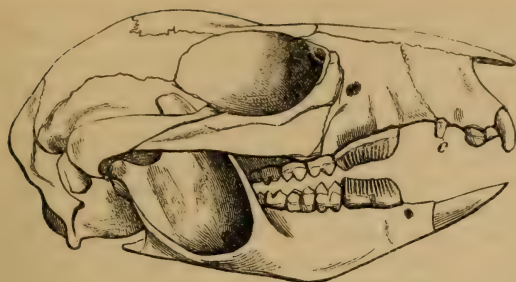
Fig. 3.—*Rat-kan-
garoo*, Hypsi-
prymnus Grayii.
*Natural   size.
From   a   skull
in   the   British
Museum.*

Fig. 4.—*Koala*, Phascolarctos
cinereus.   *A phytophagous
Marsupial.   Three-fourths
the natural size.   From a
skull in the Museum of the
Royal College of Surgeons.*

Fig. 5.—Dasyurus ursinus.   *A predaceous carnivorous Marsupial.
Three-fourths the natural size.   From a skull in the Museum of
the Royal College of Surgeons.*

are absent in one, and strongly developed in another species (*Phascolomys vombatus* and *P. latifrons*). The anterior part of the face, whether seen from above, the side, or in front, presents a stronger resemblance to the corresponding part of the Koala (*Phascolarctos*) (fig. 4, p. 313), and the Phalangers of the subgenus *Cuscus* (especially *P. maculosa*) than to that of any other known marsupials.

The ascending ramus, condyle, and angle of the lower jaw are unknown; but one important and highly characteristic part is present in the specimen in the Museum of the Royal College of Surgeons, as well as in those figured (from a cast and photograph) in the Philosophical Transactions. This is the anterior boundary of the fossa for the insertion of the temporary muscle. The extraordinary depth of this fossa and its sharply defined, evenly curved, almost semicircular anterior boundary form one of the most distinguishing osteological features of the recent *Macropodidæ**. In the carnivorous marsupials, on the other hand, the fossa is comparatively shallow. In the Thylacine the prominent upper and lower margins, approaching each other at an acute angle, scarcely meet in front, and the fossa at this part passes insensibly into the outer surface of the horizontal ramus. In most *Dasyuri* and true Opossums the margin is much more complete; and the fossa is deepest and best defined in *Dasyurus ursinus*. In the Phalangers, which are undoubtedly closely related to the Kangaroos in many parts of their organization, and which agree with them, generally, in the nature of their food, the fossa is as shallow as in the carnivorous Opossums, showing that its characters give little indication on which to found affinities in a broad sense.

Thylacoleo, in the regular wide curve and sharp definition of the anterior margin of the fossa, resembles the Kangaroos more than the Dasyures; but the shallowness of the fossa itself (deeper, however, than in any known carnivorous marsupial) decidedly shuts it out from the family *Macropodidæ* as ordinarily defined†. It is probable that herein, as in the additional small upper premolar teeth, it shows affinities with the Phalangers. This character is certainly not in itself any evidence of its relation to the Dasyures.

As far, then, as the dental and cranial characters show, I think that there can be no question that *Thylacoleo* is a highly modified and aberrant form of the type of Marsupials now represented by the *Macropodidæ* and *Phalangistidæ*, though not belonging to either of these families as now restricted.

Although these relationships are not brought out in any detail by Professor Owen, and scarcely a single comparison is instituted with the skull or teeth of any phytophagous marsupial, the quotation given above from the second paper (Phil. Trans. 1866) shows that they have been fully recognized by him. It may therefore be assumed that these are admitted facts, and we may pass to the consideration of the evidence of the predatory nature of *Thylacoleo carnifex*. Why should this animal be branded with such a direful title?

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* The Wombats present the same character in a modified form.

† *Diprotodon* also differs from the recent *Macropodidæ* in this respect.

The consideration of this subject involves a glance at the whole question, as to whether, and, if so, within what limits, the characters of an animal's teeth afford a guide to a knowledge of the nature of its food and general habits.   Although it may be asserted broadly that certain strongly marked forms of dentition are constantly associated with the function of seizing and masticating certain kinds of alimentary substances, there are so many instances of allied animals having very different dietetic habits without any corresponding modification of dental structure (to take the well-known case of the Bears, for example), that too much caution cannot be exercised before pronouncing a positive opinion in regard to any newly discovered form the habits of which are totally unknown, as is necessarily the case with an extinct animal.   I think, however, that the following proposition will be generally accepted as the first step in the process of forming a conclusion upon the subject :—That if all the known species of a large group of animals with teeth formed upon one peculiar type lead lives peaceable and inoffensive to their neighbours, and feed mainly on vegetable substances, the probabilities, in the case of any newly discovered species having teeth constructed upon the same general type, are greatly in favour of its having possessed similar habits, and been nourished by a corresponding diet.

To apply this to the present case, it is a well-known fact that all the animals belonging to the families *Macropodidæ** and *Phalangistidæ*†, including upwards of seventy species, are in the main phytophagous, feeding either on grass, roots, fruits, buds, or leaves, the larger proportion of them exclusively so, though a few (the arboreal Phalangers) are said also to partake occasionally of insects and small birds.   Not one of the group is known to be exclusively carnivorous, or ever to attack or destroy animals approaching to itself in size.

The presumption in the case of *Thylacoleo* is, therefore, that it was also a vegetable feeder ; and this presumption can only be over-ruled by pointing out some special modifications of its dental structure of such a nature and extent as to warrant our inferring a total subversion of the habits of its congeners.

In order to test how far such modifications have been shown to exist, I will cite Professor Owen's principal arguments for the predatory nature of this animal.   " In existing carnivorous mammals," he says, " the ferocity of the species is in the ratio of the ' carnassiality' of the sectorial molar, *i. e.* of the predominance of the ' blade' over the ' tubercle ;' and this ratio is shown more particularly in the upper sectorial, in which, as the tubercular part enlarges, the species becomes more of a mixed feeder, and is less devoted to the destruction of living prey.   From the size and form of the carnassials of *Thylacoleo*, especially of the upper one, we may infer that

* Equivalent to Prof. Owen's division *Poephaga*, or " Grass-eating " Marsupials.
† Equivalent to Prof. Owen's *Carpophaga*, or " Fruit-eating " Marsupials.

it was one of the fellest and most destructive of predatory beasts."
(Phil. Trans. 1859, p. 319.)

Again, " the size of the laniary canine in *Felis* being here trans-
ferred to the first incisor, its function as killer was similarly pro-
vided for by the approximation to the moving power, through the
extreme shortness of both upper and lower jaws, especially anterior
to the chief molar.   In *Felis* the small incisors are very little in
advance of the canine ; this large tooth is almost at the fore part of
both upper and lower jaws ; and in *Thylacoleo* the relative position
of the incisor tusk to the enormous temporal fossa is such as to
give it the advantage of a harder or closer grip during the action of
the powerful temporal muscles."   And further, " the chief business
of the teeth has been delegated to the tusks and carnassials ; deve-
lopment has been concentrated on these at the cost of the rest of the
normal or typical dental series.   The foremost teeth seized, pierced,
lacerated, or killed ; the carnassials divided the nutritive fibres of
prey.   *Thylacoleo* exemplifies the simplest and most effective dental
machinery for predatory life and carnivorous diet known in the
Mammalian class."   (Phil. Trans. 1866, pp. 79, 80, 81.)

In the first place, it may be replied that the great cutting pre-
molar of *Thylacoleo*, as has been already shown, bears no real com-
parison with the carnassial tooth of the Carnivora, but with the
compressed premolar of the *Hypsiprymni*.   It would certainly be to
the purpose to prove that those Rat-kangaroos which have the
largest development of this tooth show specially bloodthirsty inclina-
tions, or have any greater preference for animal food than the rest ;
but I am unable to find any evidence to this effect.   That their diet
may be composed more largely of roots than grass and leaves is very
probable ; at all events, it is known that the members of the genus
are generally more rhizophagous than the true Kangaroos ; and this
fact may perhaps afford some indication of the mode of life of *Thy-
lacoleo**.   The Phalangers of the section *Cuscus*, to which semi-
carnivorous habits have been attributed, differ completely from
Thylacoleo in the construction of the molars, and especially in having
tolerably well-developed upper canines, though, as before men-
tioned, in some of the characters of the skull (the shortness of the
muzzle, and verticality of the symphysis of the lower jaw, and con-
sequently of the incisors) they are not so far removed from it.   These
latter common characters are shared, however, by the purely phy-
tophagous and harmless Koala (*Phascolarctos*) (p. 313, fig. 4).

With regard to the second question, the peculiar adaptation of the
greatly developed middle incisors to a predatory life, exactly similar
views applied to *Plagiaulax* were thus met by Dr. Falconer :—" Let
us now test the opinion in its professed character as a physiological
deduction.   Throughout the Mammalia, where teeth perform the
function of canines ' to pierce, retain, and kill,' they are held well
apart through the interposition of a line of incisors, the end being ob-

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* The Rat-kangaroos, like so many other animals, are almost omnivorous in
confinement ; but this circumstance affords little indication of their habits in
their natural state.

vious : the points of penetration are doubled, the grasp is strengthened by widening the base, and the dilacerating and killing powers are multiplied. To arrange them collaterally in the axis would be to place them at a disadvantage to the end to be attained. But when a gnawing power is required, the middle incisors are powerfully developed, and placed collaterally in the axis of the jaws, one on each side, above and below, as typically exemplified in the placental Rodents and *Chiromys*. Doubtless a Rat, when seized, can inflict a smart wound on the hand ; but the power is a secondary attribute, complementary to the main function. Regarded in this aspect, it is negatively stamped upon the incisors of *Plagiaulax* by their collateral position that they are not constructed upon the carnivorous plan of design, nor in rational correlation therewith" (*op. cit.* p. 352).

It is certainly one of the most significant circumstances connected with the relation of dental armature to food and habits, that every known true predaceous carnivorous animal (by which I mean one which kills and eats creatures at all comparable to itself in bulk and capable of making any effectual resistance) has powerful and pointed canine teeth in both jaws, combined with comparatively small incisors, which diminish in size as they approach the middle line (see fig. 5, p. 313. A typical placental carnivore, as *Felis*, would have exemplified this even more strongly) ; and, moreover, this adaptive type of dentition is found equally well marked in animals having similar habits, both in the placental and implacental series, which differ so entirely in the far more fundamental or deep-seated conditions of organization, including the characters of dental development and succession*. This relation of canines to incisors is evidently more especially related to the predaceous mode of life than the characters of the molars. The compressed trenchant form of the crown of the carnassial tooth, for example, is a special peculiarity of the Cats and a few allied forms, and is not met with in any of the carnivorous Marsupials.

Now, to the above-described type of dentition, common to placental and marsupial carnivores, *Thylacoleo* presents no sort of an approximation : its lower canines are absent, its upper ones rudimentary and probably functionless ; its central incisors in both jaws were greatly developed. If such a dental machinery is of the most effective type for predatory life, Lions, Tigers, Hyænas, Wolves, Dasyures and Thylacines must all be ill-fitted for the part they have to play in nature's great arena.

There is certainly one group of flesh-eating animals, the Shrews and Hedgehogs, in which the type of dentition characteristic of the true carnivora is widely departed from, the development of the anterior incisors taking place at the expense of the lateral incisors and canines ; but the living prey of all these animals is comparatively small, feeble, and unresisting. They cannot on account of their habits any more than their structure be regarded as typically carnivorous : the *modus operandi* of the Hedgehog in snapping up and

* See Phil. Trans. 1867, part 2, p. 631, "On the Development and Succession of the teeth in the Marsupialia."

devouring a beetle is totally different from that of a cat in seizing and killing a rat or a rabbit ; and the dental structure is suited to each case.   In many of the smaller Dasyures, as well as in some Lemurs, which are more or less insectivorous in their habits, there is generally a tendency to enlargement of the central incisors.

There are also animals which, belonging to groups generally phytophagous, and with teeth constructed on much the same pattern as the rest, may on occasions be more or less predatory and carnivorous, as in the well-known case of the Rat, among Rodents*.   But then, how inferior is the development of these qualities in such an animal, compared with a true carnivore of corresponding size ! How mild is the ferocity and destructive power of the most predatory of Rats compared with that of its enemy the Ferret !

The interpretation of the function of the hinder teeth of *Thylacoleo* is certainly not easy ; as a herbivore with rudimentary true molars is almost as anomalous as a carnivore without canines. There is, however, no reason to suppose that the large trenchant premolars were not as well adapted for chopping up succulent roots and vegetables as for " dividing the nutritive fibres " of animal prey.

What was the particular form of food associated with the most singular dentition of *Thylacoleo*, it would be hazardous to do more than conjecture.   As the flora of the country in which this strange animal existed has probably undergone as great a change as the fauna, it is not unlikely that the material upon which it subsisted has passed away with the creature itself.   It may have been some kind of root or bulb ; it may have been fruit ; it may have been flesh. But the hypothesis that *Thylacoleo* was the destroyer of the gigantic herbivorous marsupials (many times as large as itself) with which its remains are found associated, the Diprotodons and the Nototheres, appears to me to require more proof than has yet been adduced in its favour.

What the remaining portions of this interesting animal were like, and whether its hind foot was constructed upon the syndactylous type with which the diprotodont form of dentition is at present always associated, remain to be proved by the result of further explorations in the country which has already yielded so rich a harvest of palæontological novelties.   That the Posttertiary deposits of Australia should supply forms more or less allied to those now inhabiting the same land is only what might be expected ; but that in the vastly distant ages of the deposition of the Purbeck, or still older Rhætic beds†, mammals should have existed with teeth constructed on the same or a closely similar and equally specialized type is a circumstance of much wider interest to the

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* The fact that such exceptions occur only shows the caution that should be exercised in positively assigning a particular mode of life to an animal whose habits are unknown.   We cannot by their aid justify an inference which is proved to be at variance with the larger proportion of known analogies.

† " On the Discovery of a new Fossil Mammal in the Grey Marls beneath the Bone-bed " (*Hypsiprymnopsis Rhæticus*), by W. B. Dawkins, Quart. Journ. Geol. Soc. 1864. p. 409.

geologist. I must remark, however, that, notwithstanding the resemblances pointed out so forcibly by Dr. Falconer, *Plagiaulax* appears to me to be, on the whole, further removed in structure from the existing forms than *Thylacoleo*; and as long as we have not the evidence that its cranium and upper teeth would afford, its affinities must be regarded as less definitely determined.

POSTSCRIPT.—Since the above was written, my attention has been called to some remarks "On the Dentition of *Thylacoleo carnifex*, Ow.," by Mr. Gerard Krefft, the able Curator of the Australian Museum, Sydney, in the Ann. & Mag. Nat. Hist. vol. xviii. ser. 3, p. 148, 1866, in which he gives his opinion that "this famous marsupial lion was not much more carnivorous than the Phalangers of the present time," and adds a conjectural restoration of the then unknown anterior part of the skull and incisor teeth, which subsequent discoveries have in great measure confirmed.

2. *On the* THICKNESS *of the* CARBONIFEROUS ROCKS *of the* PENDLE RANGE *of* HILLS, LANCASHIRE, *as illustrating the Author's views regarding the* "SOUTH-EASTERLY ATTENUATION *of the* CARBONIFEROUS SEDIMENTARY STRATA *of the* NORTH *of* ENGLAND." By EDWARD HULL, Esq., M.A. (Dublin), F.R.S., F.G.S., of the Geological Survey of Scotland *.

IN the following paper I purpose bringing forward some new facts recently ascertained in the district of Burnley and the Pendle Range, in confirmation of certain views advanced on a previous occasion, regarding the relative distribution of the "sedimentary" and "calcareous" strata of the Carboniferous series in the North of England. These views are published in the Journal of this Society †; and as introductory to the matter in the present communication I must ask permission very briefly to recapitulate them.

In the paper referred to, I endeavoured to prove that to the north of an old neck of land, or "barrier," which stretched across the centre of England from Shropshire, and which was formed of Silurian and Cambrian rocks, the Carboniferous strata were deposited originally upon the following plan:—On the one hand, the calcareous member (the Mountain-limestone) attained its greatest vertical development along the northern flanks of this barrier in Derbyshire, and thence thinned away northward and westward, and, as had been long since pointed out by older geologists, became intercalated with sandstones, shales, and beds of coal in the North of England and Scotland, where it appears in its most debased and attenuated form; on the other hand, the sedimentary beds of sandstone, shale, &c. were deposited in greatest force towards the north-west, diminishing in thickness towards the south-east of England,—the development of the one set of strata being in the inverse ratio of that of the other.

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* Communicated with the consent of the Director-General of the Geological Survey.   † Vol. xviii. p. 127.

This plan of relative distribution was illustrated on the map of the country by a series of lines of equal thickness (or *isometric* lines), which, I venture to think, renders the arrangement of the two sets of strata very simple and intelligible.

Confining my observations to the district north of the central " barrier " of Silurian rocks, and taking, as examples of the south-easterly attenuation (or thinning out) of the sedimentary beds, the cases of Leicestershire and South Lancashire as ascertained by the carefully measured sections of the Geological Survey, I gave the following results :—

	Thickness.
Leicestershire	3100 feet.
South Lancashire	12800 „

This augmentation of the same beds in Lancashire, as compared with Leicestershire, appeared sufficiently striking ; but subsequent investigations, while engaged in the survey of the district further north along the Pendle Range and in the neighbourhood of Burnley and Blackburn, have shown me that it falls short of the full measure of increase by several thousand feet of strata.

For some years past the geological surveyors have been autho-rized to trace each separate bed of gritstone or conglomerate in the Millstone and Yoredale series ; and these are represented in the pub-lished maps and sections by distinctive tints and patterns.   By such means alone could a true knowledge and representation of the structure of the Lower Carboniferous rocks be arrived at ; and it is only after having, with my colleague Mr. Tiddeman, traced these beds through many miles of country, and ascertained their true relations to each other, and their relative and absolute thickness by several comparative sections, that I venture to give publicity to the results they point to.   The details, however, of these sections are primarily the property of the Geological Survey, and are to appear in due course in the Memoirs ; and this being so, I must claim some amount of indulgence during the interval, and offer only the gross aggregate, as it were, preparatory to a future statement of the individual thickness of the beds.   I can venture to assert, however, that the statement I now make will not be found far from the truth when the balance-sheet is presented.

I have made three transverse sections for the purpose of ascer-taining the thickness of the Millstone-grit series, with the following results :—

Sections of the Millstone-Grit series, Pendle Range.

Locality.	Thickness.	Mean thickness.
1. Sabden, near Burnley	6500	
2. Whalley Nab	5000	5500 feet.
3. Snodworth, near Blackburn	5000	

As the Sabden section is so much greater than the other two, I do not feel so much confidence in it ; but if there is a real exagge-ration, it is reduced by taking the mean of the three thicknesses.

The results above stated will not appear unreasonable when it is

known that the Millstone series forms a range of hills with an average breadth of a mile and a half, in which the beds dip at angles varying from 30° to 50°, or even more. The Yoredale series occupies a tract of country nearly as broad, with the addition to the thickness derived from a rise in the ground in the direction of the dip. The inclination of the beds is nearly as great as that of the overlying Millstone-grit series.

The thickness of the Yoredale series has been ascertained with much precision by my colleague Mr. Tiddeman, from very clear and continuous sections in the neighbourhood of Clitheroe. Throughout the whole series of grits and shales, there occurs only 350 feet of limestone and occasional thin earthy calcareous bands. The thickness of the entire series, exclusive of the limestone above referred to, is no less than 4675 feet. If, therefore, we add to this the Millstone-grit, we get the following results :—

Thickness of Millstone-grit series	5500 feet.
Thickness of Yoredale series	4675 ,,
Total........	10175 ,,

In order to ascertain the entire development of the Carboniferous series in this district, it is necessary to add the thickness of the Lower, Middle, and Upper Coal-measures. Unfortunately for our purpose, a portion of the Middle and the whole of the Upper Coal-measures are absent from the Burnley district, having been denuded off from that area. There is, however, no good reason for supposing that these Upper beds were not originally deposited here, as there is no sensible break in the series between the Middle and Upper Coal-measures of Lancashire. I think, therefore, I shall be entirely justified in going a few miles to the southward, where these beds occur, and adding the measure of their thickness to that of the underlying beds at Burnley. Taking the thickness as fully ascertained in the neighbourhood of Manchester*, we obtain the following grand sum for the Carboniferous Rocks in Mid-Lancashire as originally deposited :—

Thickness of the entire sedimentary beds, as originally deposited in the Burnley district.

			Thickness in feet.
	Upper Coal-measures..	(Ardwick, &c.)..	2013†
Coal-measures	Middle ,,	.. (part at Burnley)	4247
	Lower ,,	.. (Burnley)	2200
Millstone-grit series		(as above)......	5500
Yoredale series		(as above)......	4675
		Total	18635

* "Geology of the Country around Oldham and Suburbs of Manchester," Mem. Geol. Survey ; also Quart. Journ. Geol. Soc. vol. xviii. p. 140. The thickness of the Coal-measures there given is 7200 feet ; but this does not include the full series of the Upper Measures under Manchester, as the upper limit is concealed beneath the Permian formation.

† This is not the entire thickness, as higher beds are concealed by the uncon-

So that, in round numbers, considering that we nowhere reach the upper limit of the Coal-measures, we may take the combined thickness of the sedimentary materials at 19,000 feet as originally deposited in this part of England.

We have now to compare these measurements with others taken at intervals along a south-easterly line, or along the direction of attenuation, Leicestershire being the extreme point where the comparison can be made in the case of the Carboniferous rocks. The thickness in these cases are also taken from sections of the Geological Survey—some measured by Mr. A. H. Green, some by myself *.

Comparative vertical sections of the Carboniferous strata from North Lancashire to Leicestershire.

N.N.W.			S.S.E.
	Burnley district.	Mottram district.	North Staffordshire.	Leicestershire.
Coal-measures	8460	7635	6000	3000
Millstone-grit series . .	5500	2500	500	50
Yoredale series	4675	2000	2300	50
	18635	12135	8800	3100

From the above comparative sections it will be observed that the beds which attained so prodigious a development in North Lancashire dwindled down to one-sixth of their volume in Leicestershire, in Central England, near which place the Mountain-limestone attains a great but unknown thickness †.

In fact, the development of these beds in North Lancashire has surpassed that of the contemporaneous beds of South Wales, hitherto considered to present the largest vertical series of Carboniferous sedimentary rocks in the British Isles; and, as far as we know, it is only exceeded in Europe ‡ by that of the Coal-field of Rhenish Prussia, where the beds, according to the estimate of Herr von Dechen, reach a thickness of over 20,000 feet. Turning to the continent of America, and taking the series of Nova Scotia as representing the maximum accumulation of sedimentary beds, we find that it is exceeded by that of North Lancashire, though, as Dr. Dawson has shown, the section is incomplete, and scarcely presents a fair point of comparison.

Professor Phillips, in his ' Geology of Yorkshire,' observes, " the thickness and purity of the argillaceous deposits being to the west,

formable overlap of the Permian and Trias at Manchester, as shown by Mr. E. W. Binney, F.R.S.   See " Geology of the Country around Oldham and Manchester."

    * Messrs. Hull and Green " On the Millstone-grit of North Staffordshire," &c., Quart. Journ. Geol. Soc. vol. xx. p. 242 *et seq.*

    † At least 4000 feet, according to sections which I levelled in the neighbourhood of Ashbourn.

    ‡ After reading the description in Sir R. Murchison's work on the Geology of Russia, I was under the impression that the beds in the coal-field of the Donetz attain a greater vertical thickness; but, from some statements by Sir Roderick himself, I found my opinion was incorrect.

and the same qualities belonging to the gritstones in the north, we may venture to suggest, as an explanation, the entrance of two distinct currents or primeval rivers, one on the west bearing sediment from the surface or region of argillaceous slate, the other from the north bearing almost wholly the granular detritus of regions abounding in gneiss and mica slate "*. Though this distinction in the distribution of the clayey and sandy members of the formation is doubtless correct in its application to Yorkshire, I doubt if it holds good with reference to the whole of the north and centre of England, where the thinning away or the swelling out of both sets of beds seems to proceed *pari passu*†. It therefore seems to me clear that we must attribute the source of the sediment generally to one and the same primeval Atlantis; and this view is strengthened by the fact that the Carboniferous sedimentary strata swell out towards the north-east of America on the shores of Nova Scotia, and tail away towards the south and west of that continent.

3. *Observations on the* RELATIVE AGES *of the* LEADING PHYSICAL FEATURES *and* LINES *of* ELEVATION *of the* CARBONIFEROUS DISTRICT *of* LANCASHIRE *and* YORKSHIRE. By EDWARD HULL, Esq., M.A., F.R.S., F.G.S., of the Geological Survey of Scotland ‡.

THE approach to completion of the Geological Survey of South and Mid-Lancashire enables me to draw up the following observations on the ages of its physical features. This district, it may be observed, lies immediately to the south-west of that which has been so faithfully illustrated by Professor Phillips in his well-known ' Geology of Yorkshire.'

The most prominent feature of the tract now to be considered is Pendle Hill (1831 feet); and as this hill is but the culminating point of a long range of parallel escarpments, physically one, stretching through a distance of 30 miles from W.S.W. to E.N.E. in Lancashire, and continued into Yorkshire, I shall take the liberty of applying the term " Pendle Range," to the whole of this line of hills.

This range commences at Parbold Hill, near Ormskirk, on the south-west, takes a straight course into Yorkshire by Hoghton Tower, Blackburn, and Whalley, and, forming the south-easterly side of the Vale of Clitheroe, continues its course towards Colne and Skipton. It generally consists of a double group of ridges, often rocky and serried, ranging in parallel lines, with intervening valleys.

The chain, when cut through transversely near its centre, presents in structure the segment of a great arch (see fig. 1) of which the axis passes by Clitheroe, and along which the Carboniferous Lime-

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* ' Geology of Yorkshire,' New Edit., Part 2, p. 188.
† For instance, the uppermost bed of Millstone-grit, or the Rough Rock, reaches a thickness of about 450 feet at Hoghton Towers, near Blackburn, one of the most *westerly* points to which we can trace it; while its average thickness is about 100 or 150 feet.
‡ Communicated with the consent of the Director-General.

Fig. 1.—*Section across the Pendle Range and adjoining district, illustrating the Pre-Permian Flexures of Lancashire.*

N.N.W.

Sykes Anticlinal.

Slaidburn Anticlinal.

Clitheroe Anticlinal.

S.S.E.

Pendle Hill.

Burnley Coal-basin.

Rossendale Anticlinal.

South-Lancashire Coal-field.

M.L. Mountain-limestone.   M.Gt. Millstone-grit.
Y.   Yoredale series.   C.M. Coal-measures.
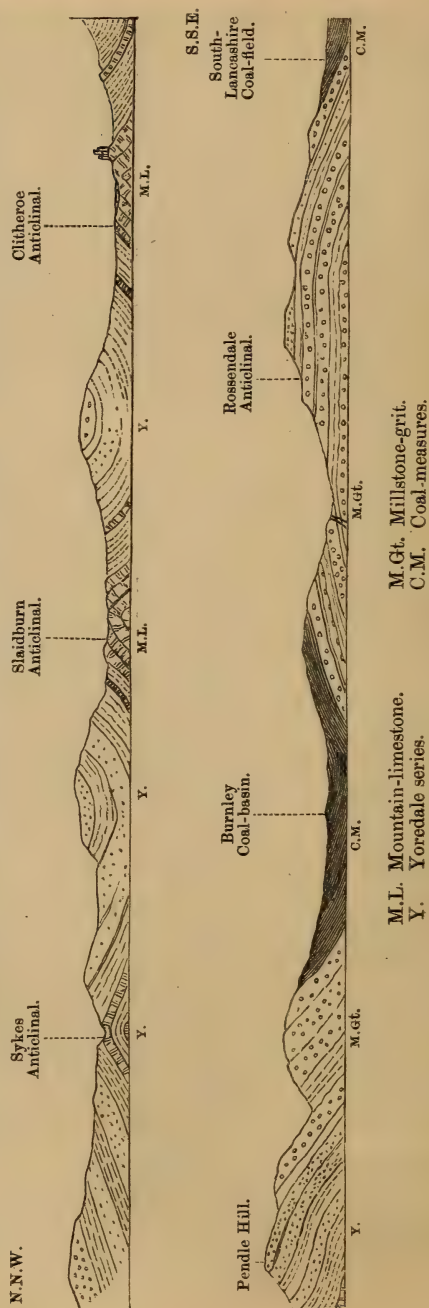
stone reaches the surface.   This axis may be traced from the banks of the river Darwen, near Roach Bridge, through Mellor, Clitheroe, by Skipton and Bolton Abbey into Knaresborough Forest, as indicated in Professor Phillips's Map of Yorkshire*.   Pendle Hill is in reality the southern segment of the arch.

North of the Clitheroe arch, there are at least two other lines of elevation, with corresponding troughs, also indicated by Professor Phillips, and recently surveyed in detail by my colleague, Mr. Tiddeman, to which he gives the names of "the Slaidburn," and "the Sykes anticlinals," the intervening synclinal being formed by Longridge Fell.

To the south of the Pendle Range there is a wide trough, giving origin to the Burnley Coal-basin †.   The northern side of this trough is formed by the Pendle range itself; and the axis passes through Blackburn, Clayton-le-Moors, Gawthorpe Park, and Marsden, in a general direction from W.S.W. to E.N.E.

The southern side of this basin is formed by the uprising of the Millstone-grit along a very flat arch, which divides the Coal-measures of the Burnley and Blackburn trough from those of the main coal-field of South Lancashire.   As the centre of this arch passes through Anglezark Moor, and through the ancient Forest of Rossendale, in an E.N.E. direction, along which line the strata are nearly horizontal, I propose calling it "the Rossendale Anticlinal" (see figs. 1 & 2).   To the south of this arch the beds roll over and dip under the South-Lancashire coal-field, which sets in by Rivington, Bolton-le-Moors, Bury, and Rochdale.   The general arrangement of these flexures will be understood by reference to the diagrammatic plan (fig. 2, p. 326).

Thus we see that the Carboniferous strata of this part of Lancashire were originally forced into a series of foldings along lines ranging a little north of east, and south of west, by the exertion (it may be supposed) of lateral pressure, which seems to have produced its most powerful effects along the line of the Pendle range.   The uprising of the beds along the low arch of Rossendale can only be regarded, as it were, as the swell from the distant wave ‡.   These several flexures are expressed in the diagram-section (fig. 1), details being omitted.

In considering this section, the physical geologist will not fail to observe how the valleys lie in the lines of the stratigraphical hills or arches, and the hills in the lines of the stratigraphical valleys, or troughs, the only exception being the Burnley Basin.   The flexures are somewhat disarranged in places by transverse faults, but on the whole are well defined.

Geological age of the flexures.—The next point to be determined is the geological age of these flexures; and fortunately for our purpose

* 'Geology of Yorkshire.'

† The position of the Burnley Coal-basin, lying between Pendle and Boulsworth Hills, is shown on the section accompanying Conybeare and Phillips's 'Outlines of the Geology of England and Wales,' 1822.

‡ Along the Vale of Clitheroe, not only are the beds inclined at high angles, but they are highly contorted.

the evidence is clear, and may be considered conclusive.   It can be shown that they are the effects of the *earliest of the three consecutive periods of disturbance, to which all the principal flexures and faults of the district may be referred.*

Fig. 2.—*Diagram of Flexures, Mid-Lancashire.*
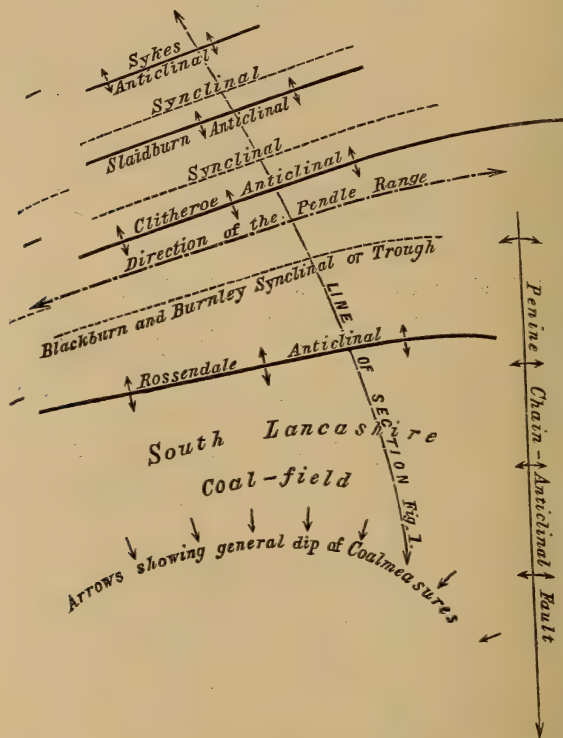
If we glance at a map of Yorkshire on which the flexures to the North of the Yorkshire coal-field are laid down*, we find that those of the Pendle range are but the extension of others in the region to the east; and I have already remarked that the Clitheroe anticlinal is continuous with that which ranges by Skipton into the Forest of Knaresborough.   The uprising of the Millstone and Yoredale series, along the northern margin of the Yorkshire coal-field, can only be regarded as a result of the same movements which have originated the flexures in the Clitheroe and Pendle districts of Mid-Lancashire; and as the Permian beds pass across denuded edges of the Carboniferous rocks, the flexures by which they are influenced are consequently anterior to the Permian period.   This is, of course, a fact long since established; but it is necessary to my argument to repeat

* I refer particularly to Phillips's map in the 'Geology of Yorkshire.'

it here, because it shows, by reasoning backwards, *that the Lancashire flexures are also anterior to the Permian period.*

But, besides this indirect, there is also direct evidence of the age of the flexures in Lancashire. At several points along the northern flanks of the Pendle range, we find patches of more recent strata, resting on the denuded edges of the Carboniferous rocks. Some of these may be of Triassic age; but, beyond question, others are referable to the Permian age, such as the red sandstones and magnesian limestones of Skillaw Clough and Bentley Brook, near Bispham, described by myself in one of the memoirs of the Geological Survey *. These Permian beds rest on others belonging to the Millstone-grit series, near the south-western termination of the Pendle range of hills. Now, from the known thickness of the Carboniferous series in this part of Lancashire, we may calculate approximately the amount of denudation before the deposition of the Permian strata ; for as these latter rest on the lower beds of the Millstone-grit, and as there does not appear to be any material break in the succession of the Carboniferous strata, it is clear that there must have been swept away part of the Millstone-grit series, and the whole of the Lower, Middle, and Upper Coal-measures, amounting to nearly 10,000 feet of strata, which may be classified as follows :—

	feet.
Upper, Middle, and Lower Coal-measures	8400
Millstone-grit series (in part only)	1500
Total quantity denuded	9900

The above seems a large estimate, but it is not overdrawn ; and it will be recollected that in my former paper, on the thickness of the Carboniferous rocks in Lancashire, I have given the details of the above measurements. The following ideal section (fig. 3), showing the relative position of the Permian and Carboniferous beds at Parbold Hill, will render my observations more plain.

It will be observed that at the foot of Parbold Hill the Permian beds of Skillaw Clough rest on the denuded edges of the Millstone series, but are again found resting unconformably on the Upper Coal-measures south of the Wigan coal-field. It is clear therefore that the whole of these Coal-measures, together with part of the Millstone series, amounting to several thousand feet, have been swept away previously to the deposition of the Permian beds along the northern boundary of the coal-field. This uprising of the Millstone-grit at Parbold Hill is merely the prolongation of the Pendle range, as stated above (p. 323).

With the proof afforded by the Permian beds at Bispham of the age of the upheaval and denudation of the Carboniferous Rocks at Parbold Hill, at the extreme west of the Pendle range, and with the evidence of the Permian beds of Yorkshire at the opposite end, it is of little importance to my purpose what may be the ages of

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* 'Geology of Wigan,' 2nd edit. (Mr. Binney, F.R.S., fully admits these beds to be of Permian age.)

several disconnected patches of newer formations, which are found at intervals resting on Lower Carboniferous rocks. I shall not, therefore, stop to discuss the age of the sandstones of Roach Bridge, near Blackburn (which, Mr. Binney, F.R.S., considers, probably belong to the Permian series[*]), nor of the sandstones of Low Moor, near Clitheroe (which will properly form the subject of a future memoir of the Geological Survey). I shall only assume them to be either of Permian or Triassic age, a fact which is beyond controversy, for the purpose of offering another illustration of the enormous denudations which have taken place before the Triassic, and probably before the Permian period, in the Vale of Clitheroe, at the base of the Pendle Range of Hills[†].

Referring to my former paper[‡] for the thickness of the Carboniferous series at this place, and premising that the red sandstones of Low Moor rest on the contorted edges of the Carboniferous Limestone beds, it is clear that the amount of strata denuded at this place is that of the Coal-measures, Millstone and Yoredale series, and part of the limestone itself, as follows:—

	feet.
Upper, Middle, and Lower Coal-measures	8460
Millstone-grit series	5500
Yoredale series	5000
Carboniferous limestone (in part)	250
	19210

or nearly 20,000 feet vertical of strata, an amount of materials at the waste of which one feels as much astonishment as at the gathering together of it. And if (as is most probable) this denudation took place

Fig. 3.—*Ideal section across the south-westerly extremity of the Pendle Range, illustrating the denudation of the Carboniferous Rocks before the deposition of the Permian formation.*

* "Further observations on the Permian and Triassic strata," &c., Mem. Lit. and Phil. Soc. Manchester, vol. iii. 3rd series.

† I regret not being at liberty to give a fuller account of the Low-Moor sandstones, which were formerly regarded as Carboniferous, but have been determined by Mr. Tiddeman and myself to be of later age. A full account will be given in a future memoir.

‡ "On the thickness of the Carboniferous rocks of the Pendle Range," *suprà*, p. 321.

in the interval between the Carboniferous and Permian periods, it cannot fail to impress us with some idea of the prodigious lapse of time necessary for the accomplishment of such a result—a lapse of time, it may be remarked, which is not represented by any known group of rocks. Here, indeed, is a blank in the ' Geological Record ' waiting to be filled up.

Along the southern margin of the Lancashire coal-field we have examples of Permian strata resting unconformably on Carboniferous, as Mr. Binney, F.R.S., has clearly shown ; but the amount of denudation there is inconsiderable as compared with that along the northern flanks of the Pendle range.

I regard it, therefore, as proved that the northern limits of the Lancashire and Yorkshire coal-fields were determined before the Permian period, and at a time when both these coal-fields were still united ; for, as I shall presently endeavour to show, the uprising of the Pennine chain did not take place till a later period, namely, after the close of the Permian. In this case the Pendle range, together with all those lines of flexure ranging across the north of England, take rank in time next to the North-Wales, Charnwood-Forest, and Cumbrian groups of hills. I shall now proceed to discuss the question of the age of the Pennine chain.

Age of the Pennine Chain.—At the time when Conybeare and Phillips* applied this term to the central range of hills which extend in a north-to-south direction from the borders of Scotland to the banks of the Trent in Derbyshire, no distinction had been attempted between the Permian and Triassic formations. Now that we are aware of the relations and important differences between these two groups of rocks, it is time to inquire to what period, whether that before or that following the Permian, the uprising of the Pennine range is to be referred ; and, as far as I have been able to ascertain, the attempt has not yet been made.

It is indeed universally admitted that the upheaval of the rocks of the Pennine chain and their subsequent denudation are of older date than the Trias, since the beds of this latter formation overlap the highly inclined Lower Carboniferous strata all along the southern extremity of the Derbyshire hills ; but the relations of these Carboniferous beds to those of the Permian stage are not so apparent, and require special investigation.

With this object in view, it is necessary to trace the course of the axis of upheaval of the Pennine chain as it occurs in Lancashire, Cheshire, and Staffordshire, which will only require short notice here, as my colleague, Mr. A. H. Green, and myself have described its course and effects on a former occasion in the Journal of the Geological Society†. We have traced this line of fracture from the neighbour-

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* ' Outlines of the Geology of England and Wales.' The authors adopted this term from the Roman name supposed to have been applied to this range of hills.

† E. Hull and A. H. Green " On the Millstone-grit," &c., Quart. Journ. Geol. Soc. vol. xx. 1864 ; also " Geology of the country around Stockport, Macclesfield, &c.," Mem. Geological Survey, by the same authors.

hood of Colne on the north to Leek and Wetley on the south, a distance of 55 miles; and in the memoir above referred to have termed it "the anticlinal fault," because it is nearly everywhere accompanied by a reversal of the dip.

Commencing on the north at Colne, "the anticlinal fault" traverses the western slopes of Boulsworth and Black Hambledon; crossing the Vale of Todmorden, it follows the margin of the high moorlands of West Yorkshire, throwing off the Millstone and Yoredale beds to the east and to the west. It then passes along the western base of Blackstone Edge, and follows the centre of Saddleworth Valley, and the moorland slopes east of Staleybridge, to Harrop Edge, accompanied by a sharp reversal of the dip. From this point it continues its course by Compstall, Disley, and along the anticlinal axis of Saltersford Valley, onward to Leek in Staffordshire; and here it passes below undisturbed beds of the New Red Sandstone, which lie in the centre of an old palæozoic trough. To the southward of this outlier it reappears, passing along the vertical beds of "Wetley rocks," and ultimately forms a junction with another fault, which traverses both Carboniferous and Triassic beds.

Now here we have the curious case of the same fault passing below the beds of the New Red Sandstone at one point without fracturing them, and coalescing with another fault which does fracture the beds of this formation. It would therefore appear as if the anticlinal fault was of two periods. I wish to draw special attention to this fact, because it is necessary to my argument.

The position and relations of the anticlinal fault with reference to the New Red Sandstone at Leek show that the primary and main fracture, and the great upheaval of the rocks of the Pennine chain which accompanied it, was of older date than that formation; but now we must endeavour to ascertain its relation to the Permian beds.

Throughout a great part of its course from Staleybridge southward, the anticlinal fault is accompanied by several parallel fractures and foldings of the strata, such as the well-known Goyt trough of Farey. These foldings are all closely connected, both by parallelism and other circumstances, with the anticlinal fault, which may be regarded as the axis of disturbance of the whole*. Amongst these parallel lines of disturbance, ranging from north to south, is the "Red-Rock fault" —an important fracture—forming the boundary between the Carboniferous and more recent formations, from Bredbury and Poynton, in Cheshire, southward for several miles. East of Stockport this fault is a downthrow of the Permian sandstone against the Carboniferous beds, and is therefore clearly of later date than the Permian formation itself; and if I am justified in assuming that the "Red-Rock fault" is contemporary with "the anticlinal fault," it is clear, by implication, that "the anticlinal fault" is also of later date than the Permian formation.

An objection to the view of the præ-Triassic age of the "Red-Rock

* Sections illustrating the relations of these flexures will be found in the paper above quoted, by Mr. Green and myself, in the Journal of the Society, vol. xx.

fault" here presents itself; for this "fault" not only dislocates the Permian strata, but those of the New Red Sandstone also, near Macclesfield and Congleton ; and it might hence be inferred that the fault is of later date than both of these formations. My answer to this objection is that there have been two periods of vertical movement along the line of the fault—one before the Triassic period, another after. Such cases (where the demonstration is perfect) are not unknown, and I can point to that of the boundary fault of the Coleorton coal-field in Leicestershire, along which there have been two distinct vertical movements in opposite directions, in post-Carboniferous and post-Triassic times. I have also already referred to the case of the "anticlinal fault" at its southern extremity and at Leek as a case of a double vertical movement.

The objection, therefore, which might be urged against the view of identity in age of the " Red-Rock " and " anticlinal " faults, owing to the displacement by the former of beds of Triassic age, seems to me to fall to the ground. Their parallelism and evident connexion with the system of flexures which range in north and south lines seem to me to point to identity of age, from which I draw the conclusion that the age of the " anticlinal" fault and of the upheaval of the Pennine chain is that which intervened between the close of the Permian and the commencement of the Trias— in other words, that it belongs to that period of general stratigraphical disturbance which marked the close of the Palæozoic age.

This is a conclusion, indeed, which has often been assumed, but it is not by any means so easily proved.

If, then, my reasoning be admitted, it follows that the Pendle range and the Pennine range belong to two entirely different lines of disturbance—different in direction, different in age—the former being referable to the close of the Carboniferous, the latter to the close of the Permian age. To these two periods Professor Sedgwick refers the Craven and Pennine faults of Yorkshire ; and looking at the parallelism in direction of the great fault which forms the boundary between the Carboniferous and Silurian rocks of the central valley of Scotland with that of the Pendle range, it seems highly probable that this great depression is also referable to the close of the Carboniferous period*.

To recapitulate in a few words—it appears, then, that immediately upon the close of the Carboniferous period the northern limits of the Lancashire and Yorkshire coal-fields were determined by the upheaval and denudation of the beds along east and west lines, while the coalfields themselves remained in their original continuity across the region now formed of the Pennine hills from Skipton southwards, and that at the close of the Permian period these coal-fields were dissevered by the uprising of the area now formed of the Pennine range by lines of upheaval ranging from north to south, nearly at right angles to the former—this perpendicularity being of itself an evidence of difference of age.

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* This great fracture has been traced by my colleagues of the Geological Survey of Scotland for many miles along the southern boundary of the coal-fields.

In the foregoing remarks I have assumed that the coal-fields of Lancashire and Yorkshire were originally united right across the area now occupied by the Millstone-grit and Yoredale rocks of the Pennine chain. That this was the case is abundantly proved by the similarity (approximating to identity) of the strata of the Millstone-grit series and lower Coal-measures on the opposite sides of the chain. This resemblance, and the identity of special coalseams, has long since been pointed out by Professor Phillips, Mr. E. W. Binney, and Mr. Warington Smyth*.

System of North-west Faults.—Of later date, still, were those disturbances which resulted in the production of faults and fractures traversing the Lancashire coal-fields from N.N.W. to S.S.E., and dislocating the strata to an extent amounting, in some cases, to more than 1000 yards.

Some of these fractures can be traced into Permian and Upper Triassic strata—for example, the New Red Marl of the Cheshire plain.

As these fractures are of more recent date than the Trias, we must descend, in all probability, to the close of the Oolitic or Jurassic period before we can arrive at the time of their production; for there seems to be no break in the sequence of the Triassic and Jurassic formations after passing the line of discordance which marks the boundaries of the Keuper and Bunter divisions of the Trias.

We shall probably not err if we assign these fractures to disturbances which occurred at the close of the Jurassic age, at the same time admitting that they may have been modified at later times.

To sum up—it seems probable, then, that the main lines of disturbance may be assigned to three distinct periods :—

1st and earliest (Pendle system), E.N.E. direction, at the close of the Carboniferous period.

2nd, next (Pennine system), N. and S. direction (nearly), at the close of the Permian period.

3rd and latest (lines of fracture), N.N.W. direction, at the close of the Jurassic period.

These may also be expressed by means of a triangle, the sides of which are parallel to the direction of the forces (fig. 4).
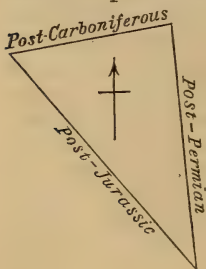
Fig. 4.—*Showing the relative ages and directions of the three principal systems of disturbance after the Carboniferous Period.*

* Introductory Address delivered to the Geological Section of the British Association, Newcastle, 1863, pp. 10, 11

PERIODS OF DENUDATION.

First Period.—Having shown, by the evidence of the unconformable patches of Permian beds on the northern flanks of the Pendle range agreeing with the position of the contemporaneous beds in Yorkshire, that the Pendle range had received its earliest outline at the commencement of the Permian period by the sweeping away of a prodigious amount of material to the north of the range, we cannot suppose that this was a solitary case. On the contrary, it is evident that the main features of the Carboniferous districts of North Lancashire and the North Riding were first shadowed forth at this same time.

This leads me to remark also that it is extremely improbable that productive Coal-measures exist under that tract of Triassic and drift-covered ground stretching inland from the coast to Ormskirk and Blackpool; for it can scarcely be doubted that the Carboniferous rocks under this tract were subjected to the same disturbances, and partook of a similar denudation to that which resulted in carrying away the Upper Carboniferous rocks from the vale of Clitheroe.

If, then, there was a period of disturbance throwing the rock-masses into a series of great folds, ranging from east to west across North Lancashire and Yorkshire, there was a corresponding and concurrent period of denudation, during which enormous masses of Carboniferous strata were swept away from these regions. These flexures died away southward, in which direction the corresponding amount of denudation was very much less, as is proved by the position of the Permian beds along the southern margin of the Lancashire coal-field. As the first movements of the Pennine system of flexures had not as yet commenced, we may suppose that whatever undulations may have been produced over the region now occupied by the high ranges of Black Hambledon, Blackstone Edge, Pule Hill, Kinder Scout, and the Derbyshire hills took an east and west direction, and were of minor importance in comparison with those which had been developed over North Lancashire and Yorkshire.

Second Period.—With the close of the Permian epoch commenced the movements which ultimately gave birth to the Pennine chain of hills, and which, by the denudation of the Upper Carboniferous rocks across the region of the central axis, caused the disseverance of the Lancashire and Cheshire coal-fields from those of Yorkshire and Derbyshire. To what extent these ranges of hills were subsequently entombed in Triassic strata is a speculative but interesting question. Recollecting the enormous vertical development of this formation in South Lancashire and Cheshire, amounting to nearly 4000 feet of strata, we may conclude that the Pennine and Pendle hills were encased in these red beds, and that to this protection they owe, to a certain extent, their preservation.

Third Period.—The third period of denudation was that which occurred after the Bunter Sandstone had been formed, and is represented

in Europe by the period of the Muschelkalk. The amount of material swept away in Lancashire at this period was probably not great ; but of the fact itself there is the most positive evidence, as the basement-beds of the Keuper rest unconformably on an eroded surface of the Bunter Sandstone at Ormskirk, Liverpool, and Birkenhead.

Fourth Period.—The long ages of subsidence and submergence of the Red Marl, Lias, and the Jurassic groups elapsed, to the close of which, as it seems to me, we must refer the system of northwesterly faults which traverse the Carboniferous, Permian, and Triassic formations. Along with the production of these fractures, which displaced the strata to the extent of 3000 or 4000 feet in some places, there must have been a corresponding amount of carrying away of materials. The result of this, and probably of other more recent denudations, has been almost to obliterate all surface indications of these enormous vertical displacements, as in the case of the great Irwell-valley fault. In other cases, where the features of the ground do happen to indicate the lines of fracture, as in the case of the Up-Holland fault, it is only to the extent of a few hundred feet, while the displacement of the beds may amount to as many thousands.

Fifth Period.—The next period of denudation of which we have any evidence in this part of the country was that immediately antecedent to the period of the Lower Boulder-clay, or Till. In this instance there was probably a combination of ice-action, sea-action, and rain- and river-action, as the rocks at Liverpool, Horwich, Whalley, Clitheroe, &c. afford evidence of glaciation below the Boulder-clay. To this period many of the primary valleys and other features of the surface are to be referred.

Sixth Period.—The beds of sand and gravel which lie between the Lower and Upper Boulder-clays afford most clear evidence of extensive erosion and denudation before the deposition of the Upper Till upon them, as I have shown in my papers on the drift-deposits of Lancashire and Cheshire. To what extent this local erosion extended to the older formations it is impossible to say ; but the effect was probably small. At the same time, in a summary of this kind, the occurrence of this period of denudation ought not to be passed over in silence.

Seventh Period.—The seventh and last period was that which ensued at the close of the Glacial epoch, and is still in existence. To this period is to be referred the channelling out of all the secondary valleys by " atmospheric denudation," and the modification by the same agency of all the physical features. Many of these valleys have been hollowed out in the lines of older valleys which had been partially filled in with drift-deposits, producing the phenomena of " valleys within valleys "*. No one, indeed, can traverse the hills of

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* A term which I have employed to describe a class of physical features not uncommon in the Pennine chain, the Cotteswold Hills, and other districts. See my paper on " Modern Views of Denudation," in the ' Popular Science Review,' October 1866.

the Pennine and Pendle ranges, and witness the enormous landslips which have taken place in the districts of the Millstone-grit*, or the masses of rock and shingle brought down by the rivers when in flood, without being struck with the actual and possible effects of rain- and river-action; but when we come to compare these with the more ancient levellings of the surface between geologic epochs, the formation of successive planes of marine denudation, such as that of the Pennine chain as it was originally, and of the region of South Lancashire and Cheshire as it is now, I cannot but feel satisfied that the results of sea-action have been vastly more important than those of frost, rain, and rivers in sculpturing the surface of this part of England during successive geologic epochs.

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4. *On a* Saliferous Deposit *in* St. Domingo.
By D. Hatch, Esq.

(Abstract.)

THE salt-mountain is situated about 15 miles from the fine harbour of Benahona, and about halfway from there to the great salt lake Emiquilla. It is 7 or 8 miles long, about 600 feet in the highest part, and varies from $1\frac{1}{2}$ to 2 miles in width. The people of that vicinity and the interior have drawn their supplies from these mines for ages, all from the upper surface. There is a coating of earth on the top, varying from 10 to 30 feet. As they have no means of disposing of the earth, they work but a short time in one place, for fear of the falling earth. They have, therefore, made holes down to the salt, but a short distance apart, nearly the entire length of the mountain. As they remove the earth from the upper surface, they frequently find masses of large crystals, some of them 8 or 10 inches square; but the great body of it is like conglomerate of West-India salt, and nearly of the same purity.

In the salt-mountain there are ledges of pure and almost transparent Gypsum, some nearly white.

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* These are specially striking in the district of the Peak, Kinder Scout and Derwent Edge.

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APRIL 22, 1868.

The Rev. John Carne, Penzance; J. Whitaker Hulke, Esq., F.R.S., F.C.S., 10 Old Burlington Street, W.; and Lewis Thomas Lewis, Esq., Gadlys, Aberdare, were elected Fellows.

The following communications were read :—

1. *On the* DISPOSITION *of* IRON *in* VARIEGATED STRATA. BY GEORGE MAW, Esq., F.L.S., F.G.S., &c.

(PLATES XI.–XV.)

CONTENTS.

OF those secondary changes which have modified the original chemical and physical constitution of rocks none seem to have more

largely affected their aspect than the recombinations and rearrangement of iron.

In continuation of this subject, treated of in a short paper read before this Society last year *, the following communication records some further observations on those forms of ferruginous variation which appear to have been due to secondary causes, subsequent to original mechanical deposition.

1. *Literature.*—It may be convenient in the first place to give a short résumé of the previous geological and chemical papers that directly refer to, or bear on the subject.

Sir Henry James, in a short paper dated May the 15th 1843, published in the 'London, Edinburgh, and Dublin Philosophical Magazine' for July 1843, notices that the disposition of the bluish-green discoloration of the Old and New Red Sandstones is independent of stratigraphical arrangement, and suggests that, as the light lines and blotches are generally adjacent to joints, the cause of the discharge of colour is due to infiltration. The author, in a note to this paper, also refers to an observation by Mr. Mallet, that "if through a fissure in a rock containing peroxide of iron a stream of water should pass containing an earthy sulphate and organic matter, the sulphate will be decomposed, and sulphuretted hydrogen evolved, which might reduce the peroxide of iron to a lower oxide." With reference to this suggestion, I will here only observe that the presence of sulphate of lime in the Keuper marls of Cheshire and Derbyshire seems to have no relation to their variegation, as the bands and crystals of gypsum occur in contact with both the red and the grey portions, and, furthermore, the grey blotches in the marl often occur independently of the presence of joints.

Sir Henry de la Beche, in the first volume of the 'Memoirs of the Geological Survey,' published in 1846, p. 254, refers to the alternation at Aust Cliff, Gloucestershire, of red marls of the Keuper with blue or greenish bands, and gives analyses of each, indicating a nearly similar composition, excepting that the iron in the blue marls was said to exist wholly in a state of protoxide, and in the red as a mixture of protoxide and sesquioxide, the amount of iron in each being nearly identical; and he attributes the difference of colour to the reduction of sesquioxide to protoxide by the agency of decaying organic matter in the lighter parts of the marl. At pp. 52, 53, 57, & 267, reference is also made to the particoloured strata of the Old Red Sandstone, in the grey beds of which carbonaceous matter and protoxide of iron are said to occur, whilst in the red beds the iron was found to be wholly in a state of sesquioxide.

The next paper bearing on the subject is one by Dr. J. W. Dawson, in the Quarterly Journal of the Geological Society, vol. v. p. 25, read May 31st, 1848, relating to the red beds of Nova Scotia. It discusses the question whether the sesquioxide of iron colouring them is in its primordial condition, or the result of a secondary change from the decomposition of iron pyrites; which latter view the author supports, and attributes the blotchy discoloration to the

* Quart. Journ. Geol. Soc. vol. xxiii. p. 114.

reconversion of the sesquioxide into bisulphide by the action of sulphuretted hydrogen produced in the decay of organic matter, and supposes that a discharge of colour may also have been due to the acids produced in the putrefaction and decay of moist vegetable matter.

Dr. Sterry Hunt, in a paper on "Chemical Geology," read before this Society, June 5th 1859, and published in vol. xv. of the Quarterly Journal, p. 488, also supports the view of Dr. Dawson, that the elimination of iron from some sedimentary strata is due to the reduction of the sesquioxide to a soluble protoxide by the action of organic matter.

Mr. H. C. Sorby, in a paper on the origin of slaty cleavage, in the 'Edinburgh New Philosophical Journal' for July 1853 (p. 3), incidentally refers to the bleaching of slates, and attributes the formation of the pale blotches to "concretions of a peculiar kind formed round bodies lying in the plane of bedding."

Mr. H. C. Sorby, in a paper in the 'Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire' for 1856–57, "On the Origin of the Cleveland Hill Ironstone," describes the replacement of carbonate of lime by carbonate of iron in shelly limestone from the Inferior Oolite—a process which will have to be referred to as a probable agent in the production of a peculiar form of variegation in the Northamptonshire Oolites.

Mr. Pengelly, in a paper on the "Red Sandstones, Conglomerates, and Marls of Devonshire," read before the Plymouth Institution and Devon and Cornwall Natural History Society, March 19th 1863, and published in the 'Transactions' of that body for 1862–63, pp. 15–38, dissents from the conclusions of Dr. Dawson, that the colour of red beds is the result of a secondary process, and enters minutely into the circumstances of the variegation of the red beds of Devonshire. To this valuable memoir I shall have occasion further to refer in the body of the paper. Although the author expresses no definite conclusions, I believe the facts pointed out for the first time by Mr. Pengelly are suggestive of the true explanation of many of the phenomena of variegation, and, I may add, agree with the views I suggested in the paper read last year before the Society, although I was not at the time aware of several of the facts Mr. Pengelly had recorded.

In a paper on the "Chemistry of some Carboniferous and Old Red Sandstones," read by Mr. J. W. Young before the Geological Society of Glasgow in March 1867, the light blotching of Red Sandstones is attributed to the presence of some organism in the sand, the decomposition of which has reduced the sesquioxide to protoxide of iron, which would be subsequently removed as carbonate by water containing carbonic acid percolating the mass; and reference is made in this paper to an observation by Mr. James Bennie, "that sand in contact with decaying roots or twigs is often found to be partially bleached."

The paper by Mr. Edward Davies, of Liverpool, on the "Action of heat or ferric hydrate in presence of water," at p. 69 of vol. iv. (new

series), for 1866, of the 'Journal of the Chemical Society of London,' records some important experiments bearing on the subject of the colour of red beds.

Professor Brush, of Yale College, U. S., in a paper on the "Native Hydrates of Iron," at p. 219 of the vol. for 1867 (new series, no. xliii.) of the 'American Journal of Science,' describes the characters of several definite hydrous sesquioxides of iron, and also refers to the investigations of Mr. Davies as doing away with the necessity of the supposition of great heat to account for the presence of anhydrous hæmatite.

Dr. J. Low, in a paper on the "Carstone of West Norfolk," read before the British Association at Norwich, this year, attempts to explain the formation of ferruginous nodules in the white sands of the Lower Greensand by the infiltration of ferruginous matter and its segregation around organic substances.

On the subject of the bleaching of ferruginous rocks by organic matter, I would also refer to a paper by Kindler, published in 'Poggendorff's Annalen' (vol. xxxvii. p. 203), and noticed in 'Bischof's Chemical and Physical Geology' (vol. i. p. 166, English edition), and also to Bischof's own experiments on the reduction of sesquioxide of iron to protoxide by organic matter ('Chemical and Physical Geology,' English edition, vol. iii. p. 1), as bearing on the theory advanced by Dr. Dawson, but which seems to be only of limited application in accounting for the variegation and discoloration of red beds.

2. *The States of Combination of Iron in the principal Stratified Rocks.*—To more readily describe the various forms of mottling and variegation which are the subject of the following analysis, it will be necessary to refer to the states of combination of the iron pervading the principal stratified rocks as a colouring-matter.

Very prominent in connexion with the subject of variegation are the red beds, including the Trias and Devonian, and also portions of the Carboniferous, Permian, Tertiary, and other formations, which are coloured with from 4 to 15 per cent. of the anhydrous sesquioxide, and contain, also, small amounts of hydrous sesquioxide, carbonate of protoxide, and silicates of iron.

The following analysis, by Mr. David Forbes, of red clay occurring as a stratum 7 or 8 feet thick at about the middle of the Shropshire Coal-measures, may be taken as representing the general composition of the unaltered portions of many red beds that have been subject to partial bleaching.

Analysis No. 74. Red "Tile Clay," Shropshire Coal-measures, Calcotts, near Broseley. (The coarse particles had been previously removed by passing the clay through a fine lawn sieve.)

Silica combined, 29·71 ⎫	64·06
Silica free, 34·35 ⎭	
Titanic acid	0·62
Alumina.....................................	20·60
Sesquioxide of iron	6·84
Protoxide of iron	0·32
Protoxide of manganese	0·09

Lime ....   0·12
Magnesia ....   0·04
Potash ....   0·91
Soda ....   0·44
Water with traces of organic matter ...   5·85
                                          ———
                                          99·89

The following analyses, however, indicate that the depth of colour of similar strata charged with the red anhydrous sesquioxide is less directly related to the *amount* of colouring-matter present than to its state of subdivision; for instance, the red clays of the Argile plastique of the Paris Basin, and of the variegated Neocomian beds near Beauvais, contain nearly 20 per cent. of red sesquioxide, whilst many sandstones of similar colour contain less than from one-fourth to one-eighth of the amount. In the one case it is in a state of fine subdivision, evenly disseminated, throughout, and intimately associated with the mass, whilst in the red sandstones it frequently occurs merely as a surface-coating to the individual grains, as, for example, in the red Millstone-grit of Cumberland, and part of the Keuper of Shropshire.

In the Old Red Sandstone of Forfarshire the colour seems to be evenly disseminated through the grains, and to have been derived from the breaking-up of an older red rock. In tracing the sources of materials from which red beds have been derived, the mechanical condition of the colouring oxide is a point of considerable interest, as indicating whether they were formed from original red beds or by the association of ferruginous matter with the other detritus at the time of deposition.

Many grey and bluish-grey beds contain a large proportion of sesquioxide of iron. Its precise condition seems to be scarcely understood, and to be worth fuller investigation. In some cases its normal red or yellow colour is evidently obscured by the presence of carbonaceous matter; but in many grey beds which contain, by analysis, a large proportion of sesquioxide of iron, the amount of carbon is not nearly enough to account for the obliteration of the normal red or yellow colour. The colours of the anhydrous and hydrous sesquioxide are given in figs. 1 & 2, Pl. XI. Burnt red earthenware, red bricks, and Venetian-red may be cited as familiar examples of the colour of the anhydrous form. The hydrous sesquioxide imparts a tint ranging from dull brown to bright yellow; and its presence in association with the anhydrous form tends to reduce the brilliancy of the colour of red beds. There are also several lower hydrates of sesquioxide intermediate in colour between the fully hydrous and the anhydrous form; but it is not practicable to distinguish them by analyses in the presence of aluminous and other hydrates.

When occurring separately in juxtaposition, as in the Folkestone beds of the Lower Greensand and in the Lower Bagshot beds, the rich blood-red of the anhydrous sesquioxide and the golden yellow of the fully hydrous sesquioxide form a marked contrast; but when they are concentrated to the extent of 15 or 20 per cent. in the matrix,

they generally both assume a brown colour, and are not so easily distinguished.

Of the colour of the carbonate of protoxide (fig. 3, Plate XI.) the cold grey of Purbeck marble and some limestones may be mentioned as examples. Between this cold-grey and the yellow and brown varieties every gradation of colour occurs, in proportion to the extent of admixture with the hydrous sesquioxide, which is readily formed as a secondary product by the peroxidation of the carbonate.

The hydrous sesquioxide, which occurs so universally as the colouring-matter of yellow sandstones, appears often to have been a secondary product, formed by the hydration of the anhydrous sesquioxide ; and the carbonate of protoxide of iron taken up in a state of solution by an access of carbonic acid, becomes immediately on redeposition converted into the hydrous sesquioxide, a familiar example of which occurs in the formation of ochreous tufa on the deposition of the carbonates of lime and iron from carbonated springs.

In contrast with the unstable character of the carbonate of iron deposited from a carbonated solution, may be noticed the permanent condition of the mineral carbonate occurring in the form of segregated nodules in, and evenly distributed through, strata charged with carbonaceous matter—a fact to be referred to in considering the probability of the bleached patches in red beds being due to the presence of organic matter.

Of the strata containing protocarbonate of iron may be enumerated the grey beds of the Coal-measures, the Oolites, and the Tertiaries, of which the following are some analyses.

Analysis No. 30, of Grey Clay from Bovey Tracey Lignite deposit.

Protoxide of iron .... 0·49 per cent.

Analysis No. 31, of Ganie Clay (Fire-clay), Shropshire Coal-measures.

Protoxide of iron .... 1·48 per cent.

Analysis No. 32, of Pennystone Clod, Shropshire Coal-measures, Benthall, near Broseley.

Protoxide of iron .... 3·75 per cent.

These determinations do not include the carbonate of iron occurring as segregated nodules.

Analysis No. 36, by Dr. Voelcker, of Grey Clay, Coal-measures, Wyre Forest, Worcestershire.

Iron, mostly as protoxide, but with traces of basic
sulphate of sesquioxide and sulphate of protoxide 3·88 per cent.
Bisulphide of iron... $\left\{ \begin{array}{l} \text{Iron ...... 0·808} \\ \text{Sulphur... 0·908} \end{array} \right\}$ ....1·716.   „

Analysis No. 37, by Dr. Voelcker, of London Clay, Bawdsey Cliff, Suffolk.

Iron, mostly as protoxide, but with traces of protosulphate and basic sulphate .... 1·68 per cent.
Bisulphide of iron ... $\left\{ \begin{array}{l} \text{Iron ...... 0·481} \\ \text{Sulphur... 0·550} \end{array} \right\}$ ....1·031   „

Analysis No. 64, by Dr. Voelcker, Kimmeridge Clay, Chapman's Pool, near Kimmeridge, Dorsetshire.

Protoxide of iron............... 1·45 per cent.
Sesquioxide of iron .... 1·04 „
Bisulphide of iron .... 0·86 { Sulphur 0·46
                                     { Iron ... 0·40
Sulphate of lime .... 0·35 per cent.
Carbonate of lime .... 34·28 „

Analysis No. 65, by Dr. Voelcker, Kimmeridge Clay, near Calne.

Protoxide of iron............... 2·08 per cent.
Sesquioxide of iron .... 4·32 „
Bisulphide of iron .:.......... 1·42 { Sulphur 0·76
                                     { Iron ... 0·66
Sulphate of lime .... 5·34 per cent.
Carbonate of lime .... 4·28 „

Analysis No. 66, by Dr. Voelcker, Oxford Clay, Brick-works, Canal Bank, Chippenham.

Protoxide of iron............... 1·12 per cent.
Sesquioxide of iron .... 3·25 „
Bisulphide of iron .... 1·10 { Sulphur 0·59
                                     { Iron ... 0·51
Sulphate of lime .... 1·37 per cent.
Carbonate of lime .... none.

The carbonate of protoxide has but a weak colouring-power; and the grey colour of the strata in whch it occurs is generally due to the presence of carbonaceous matter, which also obscures the colour of any accompanying sesquioxide of iron.

Bisulphide of iron occurring in mechanical admixture is common to beds of all ages and colours, and has but little colouring-power.

Iron pervading the older slate rocks occurs in almost every state of combination, and in all varieties of proportion, in some of the Cambrian slates almost exclusively as sesquioxide, and in others as protoxide.

Iron also occurs to some extent, with a weak colouring-power, as the basic sulphate of sesquioxide in beds in the lower part of the Ashdown Sands. Its production from the decomposition of iron pyrites will have to be referred to in accounting for some forms of variegation.

3. *On the Primary Condition of Iron in Red Beds.*—As a necessary introduction to the subject of the blotching of ferruginous strata, reference must be made to the question discussed by Dr. Dawson, on the origin of the colour of red beds, and the primary condition under which the iron was deposited. Dr. Dawson (Quarterly Journal of the Geological Society, vol. v. p. 25), in describing the red beds of Nova Scotia, suggested that the sesquioxide of iron pervading them was derived from the oxidation of bisulphide of iron under the influence of heat and moisture; he stated that bisulphide of iron is largely developed in the older rocks of Nova Scotia, and that there is no apparent earlier source for the iron in a state of sesquioxide. For the details of Dr. Dawson's views I would refer

to his paper, and will here only state the grounds upon which they seem open to question.

In the first place, the condition in which the iron occurs in bright-red clays and sandstones is principally that of the anhydrous, or slightly hydrous sesquioxide, whilst the sesquioxide ultimately derivable from the decomposition of pyrites is the yellow hydrous form. This, however, is not a fatal objection, as the experiments of Mr. Edward Davies, F.C.S., of Liverpool, recorded at p. 69 of the fourth volume of the new series of the Chemical Society's Journal, prove the possibility of the hydrous ferric oxide being reduced to a brick-red subhydrate, containing only from 4 to 5 per cent. of water, by prolonged heat in the presence of water, at temperatures considerably below the boiling-point.

The occurrence in common of bisulphide of iron both in red beds and in those containing carbonate of iron supplies an argument against the derivation of the red sesquioxide from its decomposition; indeed the decomposition of pyrites seems occasionally *to have caused the obliteration of a preexisting red colour, instead of having been the agent in its production*; but this point will be considered further on, in connexion with the causes of variegation.

Dr. Dawson further suggests that sulphate of lime in red beds may be an incidental product of the oxidation of pyrites in contact with calcareous matter; but the association of red marls and gypsum is by no means general. On the one hand, many red marls containing calcareous matter are entirely devoid, or contain but a mere trace, of sulphate of lime*; and on the other, gypsum and selenite as frequently occur in grey beds containing carbonate of iron, as, for instance, in the Lower Purbecks, Oxford Clay, Kimmeridge Clay, the French Tertiaries, and the grey marls of the Muschelkalk; and the occurrence of sulphuric acid seems to have no regular relation to the presence of either protoxide or sesquioxide of iron in strata.

The physical evidence in favour of the primordial occurrence of the anhydrous sesquioxide seems also as strong as the chemical. In the first place, there seems no *primâ facie* reason for the greater probability of the detrital accumulation of the bisulphide than of the red sesquioxide; *if* the bisulphide were specially characteristic of the earlier rocks, and the red sesquioxide of the more recent deposits, the probability of the derivation of the latter suggested by Dr. Dawson might be implied; but, as a matter of fact, disseminated bisulphide of iron is much more abundant in the Oolites, London Clay, &c. than in the earlier rocks of Cambrian and Silurian age; and, furthermore, the earliest red beds (for example the Old Red Sandstone), containing red pebbles not merely surface-coated, but red throughout their mass, prove the detrital derivation of their red colour from an earlier red rock. The red colour of the pebbles is clearly not the result of a change of colour affecting the entire mass of the old red beds; for they are associated in the red matrix

* See Analysis of Keuper marls, given at p. 370, Carboniferous marls, p. 365, and Marnes Irisées, p. 384.

with fragments of other rocks of various colours, which have not been so changed, and also with derivative fragments of dark-red marl containing more sexquioxide of iron than the general matrix.

4. *On the Bleaching of Red Beds due to Abstraction of the Colouring Oxide.*—Whatever may have been the primordial condition of the sesquioxide of iron pervading red beds, the occurrence of pale blotching seems to have almost invariably supervened on a uniformly red colour; in short, the pale portions have been produced on a red matrix, and not the red colour partially introduced on a lighter ground. This is a point at once rendered obvious by the relative disposition of the light and dark colours.

The several forms presented by the blotching of red beds have been fully described with reference to the red beds of Devon in the Memoir by Mr. Pengelly already noticed; and the accompanying illustrations (figs. 4–11, Plate XI.; 12–16, Plate XII.; 27, Plate XIV.; and figs. 41, 42, 44, 45, 49, *infrà*) represent the principal characteristics presented by the phenomena in various formations. Of all the forms that variegation takes, the occurrence of isolated blotches environed on all sides by the primordial colour seems to be most obviously independent of mechanical arrangement. In the red beds of the Bunter, Keuper, Permian, and Carboniferous, such blotches are of common occurrence, and are more often than otherwise independent of any apparent predisposing cause.

In some instances, especially in the Keuper beds, the blotches seem to have a tendency to range with the stratification; and the lines of unconnected light patches (fig. 13, Plate XII.) merge by insensible gradations into regular stratified beds of alternating colour. In other cases, as in the Permian and Grès bigarré (figs. 8 & 9, Plate XI., and fig. 12, Plate XII.), the blotching is altogether independent of the lie of the beds; and fields of light colour, obviously of secondary origin, vertically intersect alternating strata of different physical character and composition; and in contrast with this apparently adventitious disposition must be noticed the occurrence of light bands and blotches, the localization of which is evidently connected with a predisposing cause, such as the existence of vertical and horizontal joints, and of mechanical nuclei, as pebbles of various rocks, fragments of fossils, &c.

Perhaps the most perplexing point in connexion with the phenomena is, on the one hand, the apparently adventitious occurrence of the discoloured areas, and, on the other, their occasional connexion with predisposing causes—and yet, at the same time, the evident identity of the two extremes, which are connected by every variety of intermediate grade: for instance, variegation apparently determined by a line of joint will branch out and spread itself irregularly into an unjointed mass, and this again leads up to a group of isolated blotches; again, blotches formed concentrically round a mechanical nucleus, may be closely associated with blotches having no such centre, and blotches both with and without a nucleus of segregation may occur on the same piece of stone.

Another point to be noticed is the entire independence of the

range of these discoloured areas in relation to the mechanical composition of the stratum, which is well shown in fig. 14, Plate XII., representing a portion of the Old Red Conglomerate of Forfarshire, composed for the most part of red pebbles held together by a comminuted sandstone of the same material. In this example the blotches of secondary discoloration range in common through the impervious pebbles and the red matrix. In some instances the chemical nuclei of the light blotches occur in the sandstone ground, whilst the range of bleaching extends into the pebbles that happen to come within its radius; and in others the segregated nucleus occurs in the very body of the pebble, whilst the circumscribing area of discoloration spreads itself in common partly through the pebble and partly through the surrounding sandstone.

A more singular case than this occurs in the Carboniferous Limestone at Trevor, near Llangollen, where an interstratified layer of red gravel (fig. 7, Plate XI.), probably derived from the Old Red beds, is permeated by bands of greenish discoloration, which run through the loose mass, affecting the one half of individual pebbles that intersect its line of boundary, leaving the other half unchanged. This partial change of colour cannot be the effect of mere infiltration, because the pebbles lie loosely without the slightest cohesion, so that any water passing through one part of the bed must have pervaded the whole mass.

The more common forms of variegation of red beds are so familiar to geological observers that any further general description is unnecessary, and it now remains to consider the chemical composition of the several coloured areas.

The following analyses have been made with special reference (1) to the amount of the colouring oxide and of the metallic base, (2) to its state of combination in the several coloured areas, and (3) to general composition in relation to variation of colour.

The first example (Analyses, Nos. 6, 7, 8) is a nucleated form of variegation of Permian Sandstone near Coalport, Shropshire (fig. 9, Plate XI.), viz. a red ground mottled with light blotches concentrically surrounding much darker nuclei.

No.
6. The red ground contained ...... Protoxide of iron   0·538 ⎱ Metallic iron
     ,, ,, ,,   Sesquioxide of iron 1·520 ⎰ 1·470 per cent.
7. The dark central nucleus ...... Protoxide of iron   0·646 ⎱ Metallic iron
     ,, ,, ,,   Sesquioxide of iron 12·260 ⎰ 9·000 per cent.
8. Light zone, surrounding nucleus Protoxide of iron   0·010 ⎱ Metallic iron
     ,, ,, ,,   Sesquioxide of iron 0·700 ⎰ 0·491 per cent.

A somewhat similar disposition of colour occurs in the Permian Sandstone penetrated in sinking the new coal-pits at Kemberton, near Madeley, Shropshire (fig. 8, Plate XI.), in which not only the spherical nucleated blotches occur, but also discoloured bands with a central dark line of sesquioxide of iron *intersecting obliquely the beds of stratification*—a fact which suggests that the variegation in this case could not have been induced by anything interbedded with the deposition of the sandstone.

In some examples of this class of variegation the dark nuclei occur in such close contiguity that the whole of the original red ground seems to have been exhausted, leaving a uniformly light field containing the dark spots of segregation irregularly disposed. In some portions of the Millstone-grit the individual nuclei of the re-arranged sesquioxide of iron are so small that they give portions of the sandstone a freckled appearance, lighter than the general red ground, with which they alternate in irregular blotches. This is seen in the Carboniferous sandstone (Millstone-grit?) that overlies the Mountain-limestone at Lamanby and Blencow, near Penrith, of which the Penrith station is built. Some of the larger dark blotches are also nuclei of segregation; but most of them are mechanically rounded lumps of soft hæmatite, occurring both in the red and the discoloured portions. Such a combination of mechanical and secondary causes occasionally produced some singularly complex arrangements of colour, which at a first glance are difficult to understand.

The points to be particularly noticed with reference to the Coal-port example are, 1st, that the bleached zone appears due to the withdrawal of the colouring sesquioxide from the red ground into the central nucleus, the one containing less and the other more than the normal colour, and, 2ndly, that there is no evidence of change in the state of combination of the iron, except that the segregated sesquioxide becomes hydrous. In all three shades of colour the iron principally occurs as sesquioxide; and the slight differences of the proportions of protoxide and sesquioxide are so irregular that they appear unconnected with the variegation.

Some remarkable forms of this tricoloured variegation occur in the Grès des Vosges, or Upper Permian, of the East of France. Fig. 6 (Plate XI.) represents an example of fissile flagstones from the south of Raon l'Etape, Vosges, in which bleached layers occur ranging with the stratification, accompanied by the rearrangement of the sesquioxide of iron as dark nuclei in the bleached bands; and in some stones of the Grès bigarré or Lower Trias in the basement of the Palace of Industry, Paris (fig. 12, Plate XII.), the red sesquioxide has become converted into the yellow hydrous sesquioxide, accompanied by its segregation into nuclei which are ranged in lines near the boundary of the area of discoloration.

The Lower Bagshot beds near Wareham (fig. 23, Plate XIII.) present some complicated arrangements of colour due to secondary causes, of a somewhat similar character. The primordial bright red colour of these variegated beds was evidently due to anhydrous sesquioxide of iron; this has assumed the hydrous condition in irregular yellow blotches, and in places it has become segregated into a multitude of small nodular concretions, surrounded by light-grey bleached zones from which the iron has been abstracted; by this process a singularly beautiful mottling of four distinct colours has been produced out of an original uniformly red bed.

A precisely similar form of variegation exists in the Neocomian beds in the neighbourhood of Beauvais, France, where fields of bright

red and yellow interlace, here and there accompanied by nodular concretions of segregated sesquioxide.

Another phase of variegation, noticed in Mr. Pengelly's memoir on the red beds of Devon, consists of discoloured zones concentrically surrounding a pebble, fragment of fossil, or other mechanical nucleus, and evidently localized by the occurrence of such nucleus. The Old Red beds of Scotland (fig. 14, Plate XII.) and the red conglomerates of Devon (fig. 5, Plate XI.) contain frequent examples of such loss of colour; and fig. 4 (Plate XI.) represents zones of discoloration surrounding mechanical fragments of shale in the Grès bigarré, near Raon l'Etape, Vosges.

Among the various mechanical nuclei that seem to have determined the position of these spheres of discoloration, fragments of Devonian limestone in the red beds of Devon are of frequent occurrence. In a discussion on a previous paper relating to this subject, read during the late session of the Society (1867), it was suggested by Mr. Godwin-Austen that the fragments of carbonate of lime might have arrested the peroxidation of the iron, or reduced the sesquioxide to a state of protoxide in immediate contact with them, and thus have produced the zone of discoloration without removing the metallic base.

I have obtained through the kindness of Mr. Pengelly an example of such discoloration from Torbay (fig. 5, Plate XI.), and procured a determination of the iron and lime in the red ground and the area of discoloration.

Analysis No. 9, of the discoloured zone, indicated 0·81 per cent. of iron almost wholly in a state of sesquioxide, with a small amount, viz. 0·15 per cent., of protoxide.

Analysis No. 10, of the red ground, gave 2·88 per cent. of iron, nearly all of which occurred as sesquioxide, and about 0·10 per cent. as protoxide.

Both the red and the discoloured portions contained the same amount of lime, viz. 7·84 per cent. No connexion can therefore be traced between the chemical action of the limestone and the bleaching of the adjacent zone; and we have here again merely the departure of the greater part (in round numbers three-fourths) of the colouring oxide, without any alteration in the state of its combination: indeed it seems apparent that the action cannot be merely, if at all, a chemical one; for fragments of Trap and other rocks produce the same effect in the Devonshire red beds, and in the Old Red beds of Forfarshire (fig. 14, Plate XII.) and the red beds of the Grès des Vosges and of the Grès bigarré of the Vosges district (fig. 4, Plate XI.) fragments of various shales and rocks are concentrically surrounded by similar zones of bleaching.

The great majority of examples of variegation in which there are neither segregated nor mechanical nuclei exhibit similar conditions, viz. differences in the light and dark parts merely as regards the *proportion* of iron present, without any alteration in its state of combination, or change in the composition of the matrix.

The following analyses are of red Bunter sandstone, mottled

with pale blotches, &c., from a cutting on the Severn Valley Rail-
way, between Linley and Bridgnorth, similar to those in fig. 41
from near Shiffnal.

Fig. 41.—*Variegated Bunter Sandstone near Shiffnal, Shropshire.*

Analysis No. 1, of the red ground, indicated

Water of combination	0·65
Sesquioxide of iron	1·30
Alumina	0·80
Lime	0·35
Magnesia	0·75
Insoluble siliceous matter, sand	96·31
	100·16

Analysis No. 2, of the pale blotches, indicated

Water of combination	0·46
Sesquioxide of iron	0·40
Alumina...	0·36
Lime	0·26
Magnesia	0·53
* Insoluble siliceous matter, sand	98·15
	100·16

No important differences exist in the general composition of the
red and bleached parts; and the iron occurring in both was almost
entirely in a state of sesquioxide.

Sesquioxide of iron, in the light and dark parts of the Bunter
Sandstone from the south of Bridgnorth, was found to be similarly
proportioned :—

* The insoluble siliceous matter in No. 2 consisted of

Alumina and traces of oxide of iron	1·97
Lime	0·42
Magnesia	0·40
Silica	97·46
	100·25

Red Bunter, Analysis No. 23, by Dr. Voelcker, contained

        Sesquioxide of iron .... 1·84 per cent.

Grey blotches, Analysis No. 24, contained

        Sesquioxide of iron .... 0·54 per cent.

The light and dark parts of mottled Cambrian grits, Bayston Hill, near Shrewsbury (fig. 24, Plate XIII.), indicated the following differences in the percentage of the colouring oxides of iron :—

Analysis No. 11, Chocolate ground, contained

    Protoxide of iron ....
    Sesquioxide of iron ...... 7·60 } Metallic iron 5·46.
    Silicate of iron........... 0·33

Analysis No. 12.   Light blotches and bands following the joints.

    Protoxide of iron .... 0·08 } Metallic iron 2·16.
    Sesquioxide of iron ...... 3·00

The variegation resulted therefore from the departure of nearly two-thirds of the oxides of iron from the light portions without the state of combination of the remainder being much affected.

Of the states of combination, and of the proportions of iron in the light and dark parts of blotched red clays and marls, the following are examples.

Soft red clay mottled with buff, lying from 20 to 30 yards above the Sulphur-coal, Shropshire Coal-measures, Broseley.

Analysis No. 15, of the red ground, contained

    Protoxide of iron......... 0·54
    Sesquioxide of iron ...... 11·60 } Metallic iron 8·64.
    Silicates of iron .... 0·15

Another analysis (No. 35) of the same clay indicated the presence of 7·54 per cent. of sesquioxide of iron, and traces of protoxide.

Analysis No. 16, of the buff blotches and seams in No. 15, contained

    Protoxide of iron......... 0·90
    Sesquioxide of iron ...... 4·20 } Metallic iron 4·01.
    Silicates of iron .... 0·54

A determination of the iron of another example of the buff blotches (No. 16) was made at the laboratory of the Jermyn-Street Museum with the following result :—

    Total iron { Soluble..................... 1·73 } 2·41.
                 { Insoluble .... 0·68

which was present as

    Sesquioxide of iron .... 1·81
    Protoxide of iron, soluble............... 0·60 }
    Oxides of iron insoluble, } .... 0·88 } 1·48.
      weighed as protoxide...

Red Permian marl, with buff blotches (Severn Valley Railway, near Linley station):—

    Red marl (Analysis No. 4, Dr. Voelcker) contained

        Sesquioxide of iron .... 3·23
        Protoxide of iron .... 1·35
        Bisulphide of iron................................... 0·02

Buff blotches in red marl (Analysis No. 5) contained

> Sesquioxide of iron .... 2·779
> Protoxide of iron .... 1·468
> Traces of sulphur.

The general composition of the red and buff portions of the marl exhibited no material difference.

Red Permian marl, with buff blotches, near Bridgnorth :—

Red marl (Analysis No. 21, Dr. Voelcker) contained

> Oxides of iron, principally sesquioxide .... 8·76 per cent.

Buff blotches on red Permian marl (Analysis No. 22) contained

> Oxides of iron, principally sesquioxide .... 3·67 per cent.

Red Marl, Old Red Sandstone, with buff blotches (roadside, Norley, near Bridgnorth):—

Red marl (Analysis No. 13) contained

> Protoxide of iron.................. 0·90 ⎫ Metallic iron 7·00.
> Sesquioxide of iron .... 9·00 ⎭

Buff blotches on No. 13 (Analysis No. 14) contained

> Protoxide of iron .... 0·54 ⎫
> Sesquioxide of iron, probably ⎫ 8·60 ⎬ Metallic iron 6·44.
> hydrous .... ⎭   ⎭

The blotching of the red beds of the Wyre Forest Coal-field, Worcestershire (fig. 27, Plate XIV.), presents another phase of variegation, which is of frequent occurrence, viz. the bleached portions being adjacent to an overlying bed of sandstone, and branching out therefrom into the general mass of the underlying marl. As the disposition of the fields of colour is very suggestive of infiltration from the overlying beds in contact with the bleached marl, I have procured complete analyses of the red and the bleached portions.

The composition of the clay, railway-cutting near Bewdley, Worcestershire (fig. 27, Plate XIV.) was determined as follows, by Dr. Voelcker.

	Analysis No. 46 (red).	No. 47 (buff).
Water of combination.....................	6·32	4·49
Sesquioxide of iron	12·21	3·44
Protoxide of iron.........................	0·40	0·61
Bisulphide of iron	0·11	0·022
Alumina	17·57	5·33
Sulphate of lime	0·07	0·15
Lime in a state of silicate	0·71	0·71
Magnesia	2·22	0·73
Potash and soda	0·56	0·24
Insoluble silicates .... 60·29		84·35, including :—
Silica...	50·23	65·30
Oxides of iron (weighed as sesquioxide)	1·19	1·59
Alumina	6·33	14·33
Lime...	0·71	0·52
Magnesia	0·37	0·34
Alkalies and loss	1·46	2·27
	———	———
	100·46	100·07

There is somewhat more alumina in the red than in the bleached part, and a much larger proportion soluble in hydrochloric acid; but this appears to be due merely to local variations in the composition of the clay, and to be unconnected with its variegation; otherwise the general composition of the red and bleached parts is similar, the main difference being in the small amount of sesquioxide in the buff (Analysis No. 47) compared with that in the red (Analysis No. 46)— the amount of protoxide in the two colours being nearly identical, but slightly in excess in the buff portions. The change seems difficult to connect with infiltration from above, as isolated blotches of the buff occur entirely environed by the body of the red clay.

5. *On Discoloration and Bleaching connected with Joints.*—Variegation, which has evidently been more or less localized by the existence and position of cracks and joints, seems to be of several distinct kinds; one of which may be described as the simple rusting of the joint-surfaces in beds containing carbonate of protoxide of iron, and is evidently connected with surface-infiltration, for it always diminishes in proportion to the depth and distance from the surface. Fig. 20 (Plate XIII.) represents an example of grey marl that has become thus variegated; and fig. 22 (Plate XIII.) represents some beds of the Upper Purbeck marble, near Corfe, Dorsetshire. The contrast of colour between the blue centre of the slabs and the ochreous crust following the line of joints is very marked, but it is met with in some degree in all jointed beds containing protoxide of iron. This form of secondary variegation is well explained by the following analyses, by Messrs. Johnson and Sons—

No. 17. Blue Purbeck marble (fig. 22, Plate XIII.) contained

Protoxide of iron.............. 4·68 } Metallic iron 4·48 ;
Sesquioxide of iron........... 1·20

No. 18. The rusty crust of No. 17, adjacent to joint, contained

Protoxide of iron.............. 2·88 } Metallic iron 4·20,—
Sesquioxide of iron........... 2·80

and is evidently due to the partial peroxidation of the carbonate of protoxide, there being but little difference in the amount of iron present. This example is particularly instructive, as bearing on the theory of the alleged dissolution of the colouring oxide to account for the bleaching of red beds: here is an extreme case of a bed charged with the least insoluble oxide of iron, under circumstances most favourable to its removal by dissolution; but instead of its solution, the iron along the joints has become converted into the comparatively insoluble sesquioxide, unaccompanied by any material diminution in its amount. Fig. 19 (Plate XIII.) represents a somewhat similar case of joint-rusting in the Great Oolite of Northamptonshire; but in this example the rusting not only follows the joints, but concentrically surrounds some isolated balls of clay; and it was probably induced by their hygroscopic property.

In contrast with the rusting of joints, the other form of joint-variegation must be noticed, viz. the bleaching of rocks that are coloured by the red sesquioxide along the lines of jointing. The

first example is represented in fig. 42, of a vertical bleached line in the Bunter Sandstone between Linley and Bridgnorth.

The analysis of the Red Sandstone (No. 1) already given at p. 363, showed that it contained 1·3 per cent. of sesquioxide of iron, whilst the bleached seam contained less than one-third of the amount, the general composition of the stones being otherwise similar.

A rather different form of joint-bleaching, analyses of which (Nos. 11 and 12, p. 364) have also been given, is represented in fig. 24, Pl. XIII., of chocolate-coloured Cambrian Grits, Bayston Hill, near Shrewsbury, in which the discoloured bands follow the intersecting lines of jointing both vertically and horizontally, often isolating the dark ground into oblong brick-shaped forms, entirely surrounded by the bleached bands. In this the same process seems to have taken place as in the case of the Bunter, there being nearly two-thirds less iron in the light than the dark portions, with no material difference in the proportion of protoxide to sesquioxide, the insoluble sesquioxide being the condition in which it chiefly occurs throughout the rock. Now on looking at these

Fig. 42. *Bunter Sandstone, Linley, near Bridgnorth.*

bleached lines ranging with the permeable joints, they appear at first sight due to some kind of solubility and washing out of the colouring-matter; but a careful examination shows that there is no essential difference between them and the isolated spherical blotches. In the vertical bleached lines in the Bunter (fig. 42), the discoloured line is here and there interrupted and broken up into isolated blotches. In the Cambrian grits of Shropshire (fig. 24, Pl. XIII.) every gradation occurs between the discoloured joint-lines and the completely separate bleached patches; indeed all these examples serve to show how capriciously the discolouring action has been localized—in some cases strictly following the joints, and in others branching out into irregular masses that have no reference to them.

In comparing these two forms of joint-variegation, viz. the rusting of beds charged with protoxide, and the bleaching of those coloured with the red sesquioxide, it seems difficult to assign to infiltration, which has failed to remove the more soluble carbonate of protoxide of iron in grey beds, the power of removing the comparatively insoluble sesquioxide of iron adjacent to the joints in red beds.

In considering the subject of the influence of organic matter in the bleaching of red beds, certain cases will be referred to in which the acids formed during the decomposition of organic matter appear to have acted as solvents of sesquioxide of iron; but the great majority of cases, in which bleached spots and joints occur in red

beds, present features inconsistent with the mere dissolution of the colouring oxide.

The influence of joints, apart from their functions as channels of infiltration, will also be referred to in considering the phenomena of the banding of yellow sandstones (see p. 391).

There is also another singular form of banding influenced by the presence of joints, viz. in the rock-masses isolated by them. The banded purple and green beds of the Coniston Grits, represented in fig. 30 (Pl. XIV.), and in fig. 43, to which my attention was drawn by

Fig. 43. *Banded purple and green Coniston Grits, Austwick, head of Crummuch-Water beck, Clapham, Yorkshire.*
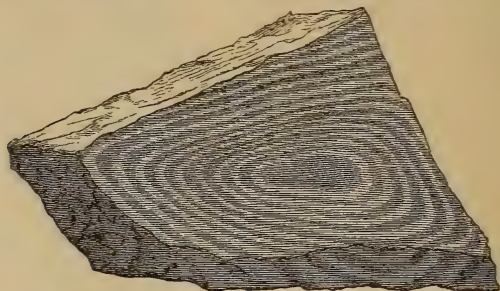
Professor Harkness and Dr. Nicholson, present the following characters. The whole mass of the rock is made up of concentric series of narrow purple and green bands, disposed without reference to the stratified structure of the rock, each nest of concentric bands being bounded by the main lines of jointing; for instance, in a triangular mass the bands concentrically follow its three sides, and in cubical portions have a square disposition, tending to curvilinear forms towards the centres. The finer cracks, which happen to die out and terminate in the middle of a mass, have also curiously influenced the direction of the banding, causing, as in fig. 30 (Pl. XIV.), a looping and deflection of the purple and green lines, as though a series of advancing lines had been arrested and held back where intersected by the joints, resulting in a structure resembling and, I believe, identical in principle with that of folded agates (see fig. 1, pl. xiii. vol. v. Geological Magazine, illustrating Mr. Ruskin's paper on " Banded and Brecciated Concretions"). The states of combination of the iron in each portion is given in the following analyses, made in the laboratory of the Museum of Practical Geology :—

Determination of iron in purple and green bands, Coniston Flags, Head of Crummuch-Water beck, Austwick, near Clapham, Yorkshire.
The purple bands (Analysis 83) contained :—

Iron { Soluble in hydrochloric acid...... 3·104 } Total 3·670 per cent.
{ Insoluble .... 0·566 }
Present as Sesquioxide of iron .. .. 1·347 per cent.
　　　　　Protoxide of iron .... 2·778   ,,
　　　　　Oxides of iron insoluble, } 0·728   ,,
　　　　　　weighed as protoxide }
　　　　　Combined water .... 1·990   ,,

The green bands (Analysis No. 84) contained :—

Iron $\left\{\begin{array}{l}\text{Soluble in hydrochloric acid } ...... \quad 2\cdot232 \\ \text{Insoluble } ..... \ .... \ .... \quad 0\cdot502\end{array}\right\}$ Total 2·734 per cent.
Present as Sesquioxide of iron .... 0·376 per cent.
　　　　　Protoxide of iron .... 2·532   ,,
　　　　　Oxides of iron insoluble, $\left.\right\}$ 0·648   ,,
　　　　　　weighed as protoxide
　　　　　Combined water........... 2·223   ,,

The rock therefore contained originally about 3 per cent. of iron, partly as sesquioxide and partly as protoxide and silicates ; and the banding appears to be due to the segregation of the sesquioxide into the concentric purple layers, the green colour of the intervening courses resulting from the *exposure* of the green silicates and the protoxide, by the removal of nearly the whole of the obscuring sesquioxide.

Many jointed rocks exhibit this secondary concentric banding *within each separate mass*, bounded by lines of joint—some merely with respect to colour, by the rearrangement of the oxides of iron ; but in others (for example, jointed granites and some Trap rocks, which exfoliate in concentric layers *within each portion bounded by joints*) there appears to have been a partial rearrangement of the mass of their constituents, and a corresponding modification of mechanical structure.

These curious phenomena seem to be more related to the *isolation* of the masses by the joints than to the mere fact of the jointing ; for in waterworn stones the direction of the lines of secondary banding is often determined by the *contour assumed after separation from the parent rock*. In the case of flints banded with yellow and grey concentric layers of iron, in different states of combination, the bands range with the waterworn outline and not the original contour of the flint.

6. *On the Variegation of the Keuper Marls.*—The arrangement of the red and grey colours in the Keuper Marls is almost as capricious and anomalous as in some of the examples already referred to ; and any satisfactory explanation is rendered difficult, on the one hand, by the disposition of colour being apparently related to stratification, and, on the other, by its being evidently the result of secondary causes. Fig. 13 (Pl. XII.) represents a portion of the section at Worcester station ; its general aspect suggests that the alternation of the red and grey bands is simply the result of interstratification ; but the interlacing outline at their junction shows that the grey beds are merely an altered condition of the red—isolated patches of grey breaking irregularly into the general red ground. There are also continuous grey beds, some of which are harder than, and of different mechanical composition from the red ; and there are isolated patches of grey, which in general have a horizontal range, coincident with the stratification ; but the recurrence of the individual blotches on their horizontal range is evidently determined by secondary causes. A portion of the beds included in the section are intersected by vertically disposed zigzag lines of hard stony matter, possibly repre-

senting former cracks and channels of infiltration; and wherever they cross the horizontal lines on which the isolated grey patches occur, the particular position of each is evidently determined by the intersection of the hard seams along which the grey patch branches, as shown in fig. 44.

A somewhat similar case occurs in the red marls interstratified with the white Keuper sandstone in the Alderley copper-mine, Cheshire.　Pockets or seams of the white sand occasionally run down from the sandstone into the marl (fig. 10, Pl. XI.), and adjacent to these seams the red marl is discoloured; and similar bleached marl bounds the line of separation of the red marl and sandstone-beds (fig. 11, Pl. XI.).

Fig. 44. *Bleached patch in Keuper Marls, Railway Cutting, Worcester.*

Again, the position of a grey patch amongst the red is frequently determined by a slightly harder condition of the stratum in a particular part.　The variety of circumstances that have determined the position of these discoloured bands and blotches, and the variety in the character of the beds that are similarly affected, show that the phenomenon is quite independent of original differences in the chemical composition of the red and grey parts of the strata; this is confirmed by the following complete analyses of the red and grey parts of the Keuper Marls, Worcester Station, that have been made for me by Dr. Voelcker:—

Analysis.

	No. 58, Red.		No. 59, Grey.
Water of combination	4·45	......	3·71
Protoxide of iron	1·60	......	1·77
Sesquioxide of iron	2·41	......	0·80
Bisulphide of iron	0·059	......	0·029
Alumina	11·14	......	12·77
Lime	4·85	......	3·71
Magnesia	3·06	......	2·17
Potash	0·69	......	0·71
Soda	traces	......	0·02
Sulphuric acid	0·09	......	0·08
Carbonic acid and loss	3·311	......	4·741
Matter insoluble in hydrochloric acid:—			

Alumina	9·39		11·72	
Silica	53·62		53·40	
Oxides of iron weighed as sesquioxide	0·78	} 68·34	0·99	} 69·49
Lime	0·64		0·61	
Magnesia	1·69		1·11	
Alkalies and loss	2·22		1·66	

	100·00		100·00

The two examples contained but slight traces of carbonaceous

matter; and their general composition was identical, excepting as regards the iron, of which there seems to have been a departure of the greater part of the sesquioxide from the grey portion. The protoxide of iron in the grey is somewhat in excess of that in the red; but the difference is scarcely more than might occur in any two portions of the same stratum, and is insufficient to prove its secondary derivation from the red sesquioxide. The mottling of the Keuper Marls seems, therefore, in principle to differ in no respect from the blotchy variegation of other red clays and marls; and the two analyses of the Worcester example are worthy of note because they fail to exhibit the kind of change in the state of combination of the iron indicated by the analyses, given by De la Beche, of the Keuper beds at Aust Passage, viz. the reduction of the sesquioxide to protoxide without any departure of the iron.

7. *On the Influence of Organic Matter in inducing Variegation.*— The connexion between the blotching and discoloration of red beds and the presence of fossil carbonaceous and peaty matter has repeatedly been noticed by geologists, and reference has already been made to the observations of De la Beche on this subject in the Memoirs of the Geological Survey. The generally accepted theory, and that suggested by De la Beche in explanation of the phenomenon, is, that the discoloration has been brought about by the reduction of the sesquioxide to a lower state of oxidation of less colouring-power by simple chemical reaction with the fossil carbon. The experiments of Bischof, and also those of Kindler, published in Poggendorff's Annalen, establish the fact that sesquioxide of iron, by simple contact with organic matter, is capable of being reduced to a state of protoxide.

With a view to ascertain how far the reduction of the colour of red beds may be due to this process, I have procured analyses of the bleached and unbleached portions of a number of examples of ferruginous strata in which the variegation seems to be connected with the presence of fossil carbon.

The mottled beds of the Woolwich and Reading series, especially in their development as the Argile plastique of the Paris Basin, are particularly instructive in explaining the nature of the secondary disposition of ferruginous colouring as apparently dependent on accompanying organic matter.

Figure 45 represents a section at Vaugirard, Paris, from the Upper Chalk to the Calcaire grossier; the mottled beds of the Argile plastique (fig. 21, Plate XIII.) included in the section are overlain by 15 or 20 feet of grey laminated clays containing beds of impure lignite and pervaded throughout by carbonaceous matter. The gradation of this character downwards seems to be connected with the arrangement of the mottling of the underlying Plastic Clay. These beds include five distinct and well-marked colours, viz. :—

    1st. The bright blood-red, which appears to have been the primordial tint;

    2nd. A light pinky red;

    3rd. A dark brown;

4th. An ochreous yellow; and,
5th. A light neutral grey.

Fig. 45.—*Section of the Argile plastique and Calcaire grossier
exposed in clay-pit, Vaugirard, Paris.*

Calcaire grossier.

Laminated clays, with
impure lignite.

a

b }Argile plastique.

c

Chalk, not visible in
the section.
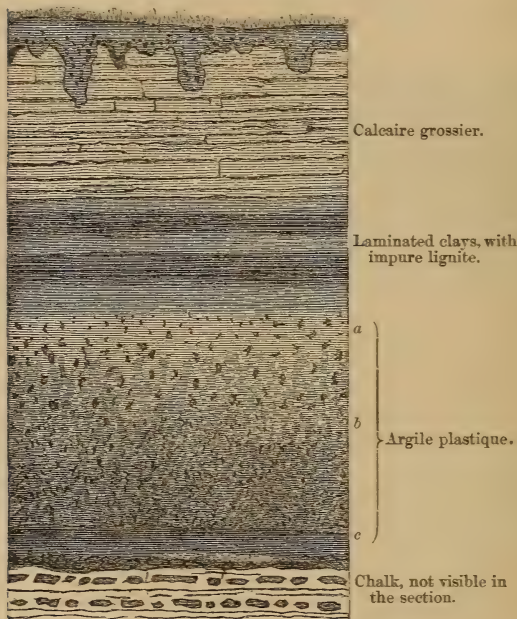
At the base (*c*), the blood-red primordial colour prevails with but
slight variegation; towards the middle (*b*) the variegation becomes
more definite, consisting of distinct patches of grey on the red or
pink ground, each of which concentrically surrounds a nucleus of
dark brown and red, as shown in fig. 21 (Plate XIII.), and is more
or less mottled with ochreous yellow. As the carbonaceous beds
are approached, the blood-red gradually dies out into neutral grey
through intermediate shades of pink; and the uppermost portion (*a*)
is variegated only by isolated brown blotches on a uniform grey
ground, such as lower down formed the nuclei of the grey patches.
The proportionate amount, and the state of combination, of the iron in
these five shades of colour will help to explain the character of this
curious and complicated variegation.

The blood-red portions of the clay, which are evidently in its
primordial condition, contain:—

(Analysis No. 53, by Dr. Voelcker) Protoxide of iron .... 0·548 per cent.
                              Anhydrous sesquioxide......... 19·641   ,,
                              Organic matter .... 0·320   ..

The ferruginous nuclei contain :—

(Analysis No. 55) .... Protoxide of iron .... 0·474 per cent.
(Hydrous) sesquioxide of iron 50·583 „
Organic matter .... doubtful traces.
Water of combination .... 7·72 per cent.

The neutral grey zones immediately adjacent to the nuclei of segregation contain only about $\frac{1}{14}$th of the proportion of iron in these centres, viz. :—

(Analysis No. 54) .... Protoxide of iron .... 0·254 per cent.
Sesquioxide of iron .... 3·779 „
Organic matter .... slight traces.

The grey portions mottled with ochreous yellow contain :—

(Analysis No. 57) .... Protoxide of iron .... 0·294 per cent.
Hydrous sesquioxide............ 3·502 „
Organic matter .... slight traces.

There is also the light-pink-coloured clay, through which the normal red graduates to the grey in the middle of the bed, and which occurs outside the grey zones surrounding the nuclei ; and here we find the iron occurring in a proportion intermediate between that in the grey and that in the full red-coloured clay, viz. :—

(Analysis No. 56) .... Protoxide of iron .... 0·254 per cent.
Sesquioxide of iron .... 5·686 „
Organic matter .... 0·790 „

Looking at these analyses, and the relative arrangement of the several colours, it is impossible to resist the conclusion that the excess of colour in the dark parts above the average composition, and its diminution in the adjacent light parts below the average, must be due to the actual passage of the iron to the centres of segregation. Here also, as in most other cases of segregation, the motion of the sesquioxide of iron is accompanied by its becoming hydrous, the blood-red of the ground being exchanged for a rich ochreous brown in the nuclei, and bright-yellow rust partially stains the exhausted portions. There is one point in connexion with the variegation of these mottled clays which seems difficult to explain satisfactorily, viz. the existence, about the ferruginous nuclei in the grey ground, of small patches of the blood-red clay quite unaltered, neither depleted nor enriched.

Among other cases of variegation apparently connected with the presence of organic matter, the following may be referred to. Fig. 25 (Plate XIII.) represents a yellow surface-clay containing fragments of black carbonaceous matter, adjacent to which the clay has been bleached of a pale-grey tint.

Analyses of the grey and yellow portions gave the following results :—

The yellow clay (Analysis No. 60, Laboratory of the Museum of Practical Geology) contained

Total iron, Soluble .... 2·81 } 3·55 per cent.
     „   Insoluble .... 0·74 }

Present as { Sesquioxide of iron .... 3·20   „
            { Protoxide of iron, soluble.............. 0·74   „
            { Oxides of iron weighed } insoluble ... 0·96   „
               as protoxide .... }

The grey patches adjacent to carbonaceous matter (Analysis No. 61) contained

Total iron, Soluble .... 0·54 } 0·94 per cent.
     „   Insoluble .... 0·40 }

Present as { Sesquioxide of iron .... 0·16   „
            { Protoxide of iron, soluble.............. 0·55   „
            { Insoluble oxides of iron, weighed as } 0·52   „
               protoxide .... }

Another, somewhat similar case is illustrated in fig. 46, of red surface loam (rearranged Keuper marls, in a railway-cutting between

Fig. 46.—*Red Surface-loam, consisting of rearranged Keuper marls, in a railway-cutting between Codsall and Albrighton, Shropshire.*

Bleached drift.

Red drift.

Keuper marls.

Keuper sandstone.
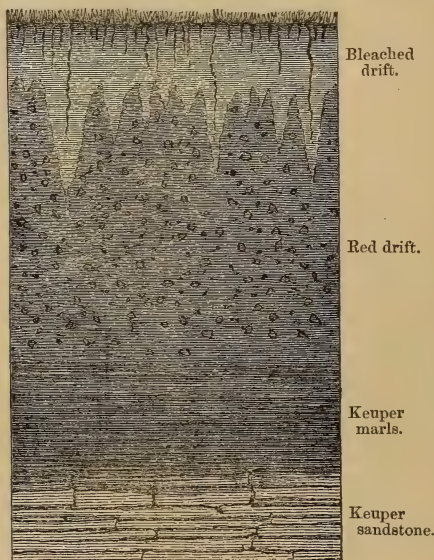
Codsall and Albrighton, Shropshire) intersected by seams and pockets of bleached grey loam, apparently connected with the penetration of roots from the surface.

The red loam (Analysis No. 67, Laboratory of Museum of Practical Geology) contained

Total iron, Soluble .... 2·46 } 2·69 per cent.
    ,,   Insoluble............................ 0·23 }

Present as {
Sesquioxide of iron........................ 3·06   ,,
Protoxide of iron .... 0·41   ,,
Oxides of iron weighed as } insoluble 0·29   ,,
    protoxide ....
Carbon.................................... 0·188   ,,

The discoloured seams and pockets (Analysis No. 68) contained

Total iron, Soluble .... 0·58 } 0·73 per cent.
    ,,   Insoluble .... 0·15 }

Present as {
Sesquioxide of iron........................ 0·55   ,,
Protoxide of iron, soluble .... 0·25   ,,
Oxides of iron weighed as } insoluble 0·20   ,,
    protoxide.................
Carbon .... 0·114   ,,

The disposal of the oxides of iron which in this case have been
withdrawn from the bleached portions is not evident; but in an
example pointed out to me by Mr. J. W. Young, of Glasgow, the
iron has been aggregated as hydrous sesquioxide into tubular con-
cretions (fig. 47, *a, b, c*) concentrically disposed around roots pene-
trating the Post-tertiary clays about Glasgow, their transverse section
(*d*) exhibiting a banded arrangement.

Fig. 48.—*Bleached sand under
peaty gravel. Cliff east of
Southwold, Suffolk.*

Fig. 47.—*Concretions of hydrous
sesquioxide of iron, Post-tertiary
clays, Glasgow* (actual size).
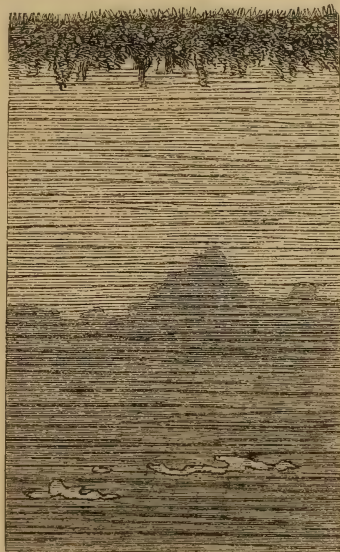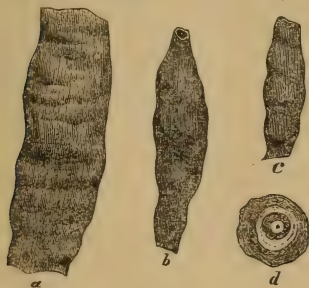
In the cliff between Southwold and Easton-Bavent, in Suffolk
(fig. 48), a surface layer of peaty gravel has bleached the bright-

yellow sands overlying the Chillesford clay to a depth of ten or twelve feet—the light-grey sands under the carbonaceous surface-layer joining on to the golden-yellow sands in the bottom of the section with an outline not corresponding with the stratification.

In a Freestone quarry, Keuper Sandstone, Clive Hill, Shropshire (fig. 49), the bleaching effect of organic matter is again evident.   In

Fig. 49.—*Red, buff, and brown Keuper Sandstone, Clive Hill, Shropshire.*
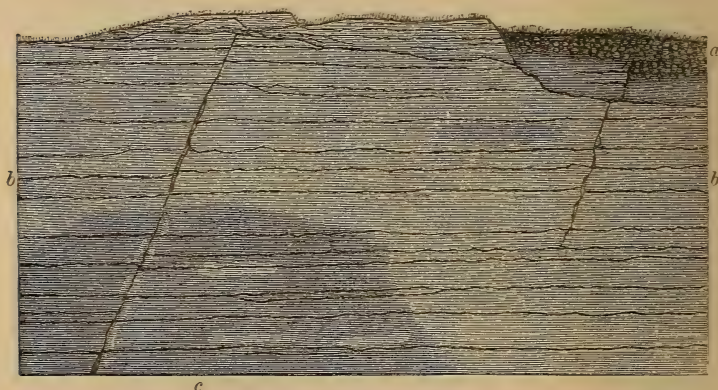
the top of the quarry dark-brown sandstone (*a*), spotted with cream-coloured blotches (fig. 40, Plate XV.), occurs with the following composition, determined by Dr. Vœlcker :—

	Analysis No. 62. Brown ground, *a*.		No. 63. Buff blotches on *a*.
Organic matter, humic and ulmic acids		1·22	0·31
Protoxide of iron, with traces of sesquioxide too small tobe separately determined }	......	0·42	0·32
Alumina		0·36	0·26
Lime		0·06	0·06
Sulphuric acid		0·08	0·07
Magnesia and traces of alkalies		0·26	0·34
Insoluble siliceous matter:—			
Alumina	2·44 ⎤		1·35 ⎤
Oxides of iron	0·31 ⎥		0·30 ⎥
Lime	0·47 ⎬97·60		0·43 ⎬98·64
Magnesia and loss	0·08 ⎥		0·19 ⎥
Silica	94·30 ⎦		96·37 ⎦
	100·00		100·00

The buff blotches were hard and crystalline, standing out from the weathered surface of the rock, and they may be segregations of silica; the colour of the brown ground is due to the presence of the organic acids.   The bottom of the quarry exposes red sandstone (*c*), joining on with an irregular outline to the overlying mass of cream-

coloured rock (*b*), the bleaching of which and loss of red colour appears, as in the case of the Southwold section, to be connected with infiltration from the uppermost bed charged with humic and ulmic acids.

A somewhat similar case is given in fig. 17, Plate XIII., of a specimen (in the Museum of the Jardin des Plantes, Paris) of a carbonaceous fossil in red Carboniferous sandstone at Ardenay, in which the colour immediately adjacent has been bleached.

The bleaching-power of carbonaceous matter is further illustrated in fig. 26, Plate XIII., of the Lower Green Sand near Folkestone, where some carbonaceous spots are surrounded by discoloured zones, and these again concentrically surrounded by bright-yellow rings of hydrous sesquioxide of iron, which appears to have been displaced from the central area. Similar bleached patches frequently occur in the sands of the Crag district; and these, as in fig. 50, are always surrounded by a zone *darker than the general colour of the sands*, and coloured apparently by the iron withdrawn from the lighter area.

Fig. 50.—*Bleached patch in yellow ferruginous sands accompanying the Crag, Wangford Crag-pit, Suffolk.*

These phenomena present two distinct points for consideration:—first, simple chemical reaction and the mechanical washing out of the iron in a soluble condition; secondly, the rearrangement of the colouring oxide, which cannot be explained by simple chemical and mechanical agencies.

Both of these processes seem to have operated in the production of those variegations of ferruginous strata which are connected with the presence of organic matter.

The Southwold, Clive Hill, and Codsall examples of bleaching appear to be the result of simple dissolution, and mechanical removal of the iron brought into a soluble condition. The generally accepted explanation, and that originally suggested by De la Beche, is, first, the reduction of the colouring-power of the iron by the conversion of the sesquioxide to protoxide, from deoxidizing contact with organic matter, and, secondly, the dissolution of the protoxide thus formed by carbonated water.

The experiments by Kindler and Bischof (Chemical and Physical Geology, vol. iii. page 1, English edition) establish the possibility of these reactions; but it is remarkable that in none of the cases that have been made the subject of the foregoing analyses does the bleaching appear due to *simple deoxidation*; and, furthermore, the proportion of protoxide to sesquioxide of iron is not increased in the bleached areas of red beds.

In grey beds accompanying carbonaceous deposits the iron is almost wholly in a state of carbonate of protoxide, and the nodules of

segregation are also carbonate of iron. Ferruginous nodules of segregation connected with the variegation and depletion of red beds, however, invariably consist of the sesquioxide. Carbonic acid *per se* is impotent in either reducing sesquioxide of iron to the lower oxide or in dissolving it. If, therefore, interbedded carbonaceous matter has operated as a solvent of sesquioxide in red beds by its reduction to protoxide, its effect must be limited to the parts in immediate contact ; and it seems difficult to explain on this theory how, as in the case of the bleached beds at Southwold and Clive Hill, the operation can have extended to a distance of ten or twenty feet from the carbonaceous matter.

The direct solvent action of humic, ulmic, and other acids the product of organic decomposition, appears a more probable agent of dissolution, and does not necessarily involve the reduction of the sesquioxide to protoxide. According to Bischof (Chemical and Physical Geology, English edition, vol. i. p. 166), humic acid occurring in vegetable mould forms a compound with sesquioxide of iron soluble in 2300 parts of water and crenic acid, a combination soluble in ammonia. The formation of limonite or bog-iron-ore appears to be the result of such dissolution ; it consists of sesquioxide of iron in combination with variable amounts of humic acid (Dana's System of Mineralogy, p. 178, fifth edition). The aggregation of sesquioxide of iron around roots and other vegetable remains in bogs may thus be incidental to its temporary dissolution by the acids of organic decomposition.

These simple chemical reactions, though coordinate with them, will not, however, fully account for such phenomena of variegation as those presented by the Argile plastique and Lower Greensand, in which the variegation has resulted not *from the loss of the iron in a soluble condition, but from its rearrangement,*—in the one case centripetally, resulting in its aggregation to concentrated nuclei surrounded by a depleted area ; in the other centrifugally, the rearranged oxide of iron circumscribing the depleted area from which it was dispersed.

8. *On Variegation due to the Decomposition of Bisulphide of Iron.* —Among the secondary changes of colour from an altered state of combination, must be noticed that due to the oxidation of bisulphide of iron, which frequently occurs mechanically disseminated in sedimentary strata. Its simple oxidation, as is well known, results first in the production of sulphate of protoxide of iron and free sulphur, and ultimately, by the further decomposition of the protosulphate, of a rusty deposit of the hydrous sesquioxide. When iron pyrites occurs in mechanical association with grey beds charged with carbonate of protoxide of iron, as in the case of the London clay, the ultimate result of the decomposition appears to be limited to the production of the sesquioxide ; but in a case which has come under my observation, a more complicated change appears to have taken place, involving the bleaching of beds charged with the anhydrous sesquioxide.

At the base of the Ashdown (Wealden) sands under the East Cliff, Hastings, occurs a bed of light bluish-grey tenacious clay, here and

there tinged with red, and somewhat resembling in physical character the white Tertiary clays; but instead of burning of a light cream-colour in the kiln, the presence of much iron was indicated by the fire changing it to a dark yellowish-brown colour.

An analysis by Dr. Voelcker (No. 38) indicated that it contained nearly $1\frac{3}{4}$ per cent. of iron occurring as

Basic sulphate of sesquioxide .... 1·68 per cent.
Bisulphide of iron .... 0·094 „

Patches of pinky red in portions of the clay indicated the former presence of the iron in a state of anhydrous sesquioxide, which also occurs largely in the middle beds of the Wealden.

The partial decomposition of the pyrites, of which some still remains, seems to have brought about the discoloration. It appears that the whole of the sulphur of the decomposed pyrites has become oxidized, and has entered into combination with the ferric oxide, producing the neutral grey basic sulphate; and the original light-red colour of the bed has thus became partly obliterated. This is the only case of discoloration distinctly traceable to the decomposition of bisulphide of iron that has come under my notice; and few red beds contain a sufficient proportion of pyrites to convert by its decomposition the whole of the colouring sesquioxide into the almost colourless basic sulphate; but the case, though exceptional, should be recorded among the phenomena of variegation.

9. *Variegated Cambrian Slates.*—The variegation of Welsh slates, of which examples are given in figs. 29, 31, and 32 (Plate XIV.), and which seem to be the result of a combination of sedimentary and secondary causes, is of two kinds:—first, that consisting of well-defined blotches and bands disposed with more or less continuity, and always in harmony with the stratification; and, secondly, the conversion of the blue and purple slates to green, in contact with Trap dykes, and in large fields of colour interlacing irregularly with the normal colours, and disposed without regard to the stratification they vertically intersect.

These two forms of variegation appear to be due to independent causes.

The first case of stratified variegation (illustrated in fig. 32, Plate XIV.), when most fully developed, occurs in the form of interrupted green bands of two shades of colour, viz. dark olive-green layers of mechanical constitution different from that of the slate, and adjacent to them a zone of light-green discoloured slate, sometimes occurring on both the upper and under side, symmetrically enclosing the dark layer as a central nucleus, but frequently occurring only on the under side.

Having but recently described these beds in the Geological Magazine [*], I need now only state that whatever may be the precise nature of the dark olive-green bands, it is evident they are of mechanical origin, and not the result of secondary segregation. Though often continuous for many yards, they are generally interrupted at

[*] Geological Magazine, March 1868, vol. v. p. 123.

intervals, and there exist all gradations between the continuous bands and isolated blotches.

These spherical bleached blotches generally contain a small nucleus of matter identical with that composing the dark-green layers, though not always visible, from the line of cleavage failing to intersect it.

The questions suggested by these phenomena refer to the time at which the bleaching took place. Was it before, or concurrent with, the slaty cleavage? and was the alteration of colour due to a change in the *condition*, or in the *amount*, of the colouring-matter? The first question is easily answered; for, as has been shown by Mr. Sorby, the form of the blotches has been notably affected by the cleavage attenuating them on the transverse section, whilst on the cleavage section they exhibit no distortion. I find also that the bands and blotches have partaken of all the movements affecting the slate, and are frequently broken by faults and dislocations. It is evident, therefore, that the bleaching was antecedent to, and independent of, the cleavage.

The composition of the discoloured spheres and bands adjacent to the green layers points to a conclusion respecting their character different from that arrived at by Mr. Sorby, that " they have been *concretions* of a peculiar kind, formed round bodies lying in the plane of bedding" (" On the origin of Slaty Cleavage," Edinburgh New Philosophical Journal, July 1853); for analyses of the purple and discoloured portions of the slate, which have recently appeared in the ' Geological Magazine' (vol. v. p. 123, March 1868), exhibit no material difference in general composition, and no aggregation of matter in the light parts that is not also found in the body of the slate; in short, they are identical, excepting that there has been a departure of about two-thirds of the sesquioxide of iron out of the bleached portions.

The blue slate, Glyn quarries, Llanberis (Analysis No. 45), contained

Sesquioxide of iron .... 5·68
Protoxide of iron .... 0·46

and the bleached bands underlying the dark-green layers (Analysis No. 44) contained

Sesquioxide of iron .... 1·59
Protoxide of iron .... 0·22

and appear to be precisely analogous to the discoloured spheres and bands in red beds. In these it has already been observed that matter of various kinds, as pebbles, fragments of stones, and fossils, has evidently induced and localized the motion of the colouring sesquioxide; so in the case of the banded slates, the layers of interstratified green matter appear to have similarly incited the departure of the sesquioxide of iron from the adjacent slate, without inducing any change in its state of combination. In the discoloured spheres of the red beds the iron withdrawn therefrom was frequently found to be segregated into small central nuclei; and it appears probable that the

sedimentary green layers and spots to which the bleached slate is adjacent may have received as an accession the sesquioxide of iron abstracted from the surrounding zone.

The case of discoloured blotches from which the iron has been discharged, without any centre of aggregation, is more difficult to account for; but some examples of banded slates in the Penrhyn Quarries, given in fig. 31 (Pl. XIV.), seem to suggest an explanation; the light discoloured bands are concentrically surrounded by a dark band, darker than the slate, apparently by an excess of the colouring oxide, as though the oxide of iron had been dispersed centrifugally to the outline instead of aggregated to the centre; and it was observed that the mechanical layer forming the centre of the discoloured band is lighter in colour than where no such external dark zone occurs.

The other form of secondary variegation, viz. the conversion of the blue and purple slates to green in large fields of colour, and to green slate in contact with the intrusive greenstone dykes, appears to have no relation to that just described. An analysis (No. 29, by Dr. Voelcker) of an example from the Penrhyn Quarries showed that it contained 8·26 per cent. of iron, equivalent to 10·63 per cent. of protoxide as compared with (Analysis No. 27) 11·40 per cent. of sesquioxide in the purple slate of the same quarry. There is therefore no material departure of colouring oxide from the green variety, and we must look for an alteration in its state of combination to account for its change of colour.

The slates of a uniform green colour have no stratigraphical horizon distinct from that of the blue and purple varieties. The highest beds of slate in the Penrhyn Quarries (fig. 29. Pl. XIV.), underlying the uppermost Cambrian grits of Bronllwyd, and marked separately 10 and 11 in Professor Ramsay's section, No. 59 (p. 156, Geology of North Wales, Memoirs of Geological Survey), exhibit, on a large scale, this interchangeable colouring. The highest portion of No. 11 is more generally green, and purple prevails in No. 10; but there is no distinct line of demarcation between the two colours, which interlace with each other in a direction *vertical to the stratification.*

The purple (Analysis, No. 27) contained

Protoxide of iron	0·874
Sesquioxide of iron................................	6·540
Sulphur	0·031

The green (Analysis, No. 28) contained

Protoxide of iron	5·49
Bisulphide of iron	0·15

A second analysis of No. 28 gave 5·90 per cent. of protoxide of iron. The change of colour is therefore due to the conversion of the sesquioxide of iron into protoxide; there was also about one-sixth less iron in the green than in the purple, a difference insufficient to explain the change of colour, but accounted for by the fact

that the green slate contains local deposits of segregated iron as crystallized pyrites.

An example of green slate, converted from the purple in contact with a dyke of diabase, Dinorwic Quarries, Llanberis (Analysis No. 52), contained

$$\begin{array}{ll}
\text{Protoxide of iron} & \text{5·568} \\
\text{Sesquioxide} & \text{3·133} \\
\text{Sulphur} & \text{0·011}
\end{array}$$

Under the microscope the protoxide of iron appeared to occur as chlorite. The production of great masses of green slate can therefore be explained by a simple chemical process, viz. the partial reduction of the sesquioxide to a state of protoxide, and the separation of a small proportion as bisulphide rearranged as distinct crystals. The green banding of the Cambrian slates, and the production of the large uniform masses of green, were therefore not only due to independent causes, but occurred at different times,—the banding and blotching before the slate was cleaved; and some of the green slate was converted from the purple at the time of the intrusion of the greenstone dykes, which Professor Ramsay regards as of Post-carboniferous age.

10. *On the Discoloration of Red Beds by Lime and Magnesia.*— The absence of red beds from strata that are interstratified with calcareous bands, and the general absence of calcareous matter from red beds, must be noticed in connexion with the following examples of secondary variegation, which seem to be connected with the presence of carbonate of lime.

De la Beche, at page 53 of vol. i., Memoirs of the Geological Survey, notices that many of the green and blue bands in the red marls of the Old Red Sandstone of Herefordshire were found to be calcareous, or half-developed cornstones. With this exception, the large extent of non-calcareous *red* rock of the Old Red Sandstone forms a striking contrast with the great thickness of Upper Silurian *dun-coloured* beds that underlie it, and in which the calcareous element prevails. This is expressed in fig. 51, exhibiting an entire absence of red beds, from the top of the Ludlow rock to near the base of the Wenlock shale, where a reddish-purple bed appears.

This fact is not accounted for by the absence of ferruginous matter, as the Wenlock and Ludlow dun-coloured shales contain as much iron as the Devonian red beds above, and the purple bed below. It seems, however, to be directly correlative with the presence of carbonate of lime. In Shropshire the proportion of lime gradually increases upwards, from the purple bed as a minimum, at the base, to the massive limestone as a maximum, at the summit of the Wenlock beds.

An analysis (No. 51) of this purple bed at Minton, near Little Stretton, shows that it contained

$$\left.\begin{array}{ll}
\text{Protoxide of iron} & \text{0·72} \\
\text{Sesquioxide} & \text{7·70} \\
\text{Insoluble oxides} & \text{0·75}
\end{array}\right\} \text{Metallic iron 6·27,}$$

and about $7\frac{1}{2}$ per cent. of carbonate of lime.

Fig. 51.—*Sketch-section showing the Relation of Grey Beds to Calcareous Strata, Upper Silurian formation, Shropshire.*

Old Red Sandstone. Cornstone. Upper Ludlow. Aymestry Limestone. Lower Ludlow. Wenlock Limestone. Wenlock Shale. Purple bed. Penta-merus Lime-stone. Lower Silurian rocks.

Non-calcareous, *red.* Calcareous, *grey and dun-colour.* Calcareous, *grey.* Non-calcareous, *purple.*
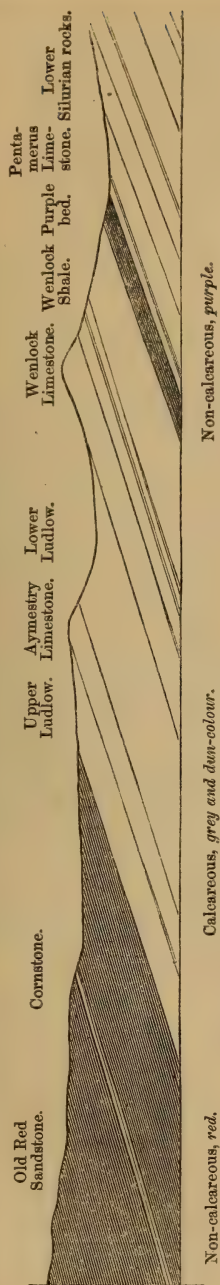
Fig. 52.—*Sketch-section showing the Relation of Grey Beds to Calcareous Strata in the Trias of the East of France.*

Grès des Vosges. Grès bigarré, or Bunter. Muschelkalk. Marnes irisées. Grey calca-reous bands in Marnes irisées. Lias and Oolites.

Non-calcareous, *red.* Calcareous, *grey.* Non-calcareous, *red.* Calcareous, *grey.*
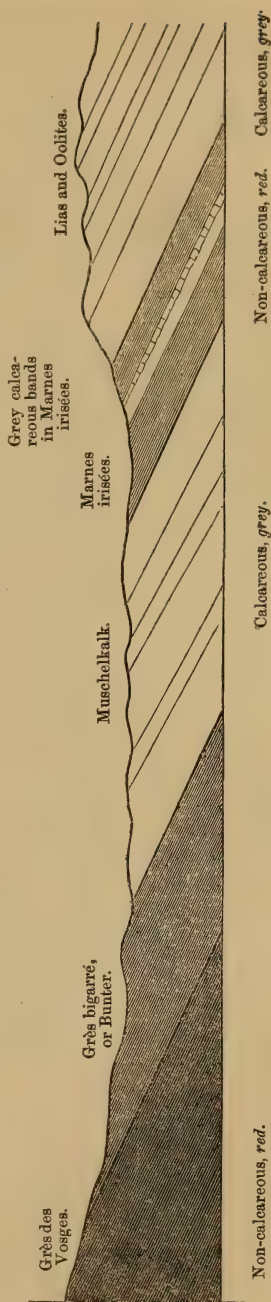
This purple bed scarcely occupies a distinct stratigraphical horizon, but passes upwards, with a blotchy interposition, into the great mass of overlying dun-coloured beds.

An analysis (No. 50) of these from between Harley and Much Wenlock indicated the following composition :—

Protoxide of iron .... 1·80 ⎫
Sesquioxide of iron ...... 7·00 ⎬ Metallic iron 7·01,
Insoluble oxides of iron . 0·35 ⎭

with about $9\frac{1}{2}$ per cent. of carbonate of lime, besides calcareous nodules of segregation.

There is no material difference in the amount of the iron ; the sesquioxide in the purple bed appears to exist as the *anhydrous* form, and that in the dun-coloured beds as the *hydrous*; and the proportion of protoxide to sesquioxide increases upwards with the increase in the amount of calcareous matter, until in the blue beds of the Wenlock limestone the iron exists principally as carbonate of protoxide. The relation of this dun-colour to the presence of lime is further supported by the fact, that where the calcareous Pentamerus-zone appears between the purple bed and Llandovery conglomerate, it is accompanied by dun-coloured, and not purple shales, and where the band of Woolhope limestone appears in Herefordshire on the horizon of the purple bed in Shropshire, the purple colour is lost. The same principle appears to hold good with respect to the distribution of colour in the Trias of the east of France, a sketch-section of which is given in fig. 52.

In the neighbourhood of Lunéville, near Nancy, the red colour of the Marnes irisées disappears in descending to the Muschelkalk, the calcareous bands being interstratified with grey marls ; and again, when the Muschelkalk is passed, and the calcareous element goes out, the red colour reappears in the Grès bigarré or Bunter. The same relation of colour to calcareous matter is observable within the Marnes irisées, and is illustrated in fig. 15 (Pl. XII.), representing a section at Enville near Lunéville, in which the change of colour from red to grey seems to have been induced by the presence of bands of magnesian limestone. Immediately adjacent to these the marl is of a uniform grey colour, and the underlying red colour begins to come in as small isolated spots and lines ; these gradually increase in proximity until they graduate, through a red ground freckled with grey, into the mass of the uniformly red marl.

The following analysis by Dr. Voelcker gives the composition of the interstratified calcareous layers, and of the red and grey parts of the Marnes irisées at Enville near Lunéville.

Analyses.	No. 69. Red marl.	No. 70. Grey marl.	No. 71. Hard band.
Water of combination	4·24	3·97	1·73
Bisulphide of iron............	0·05	0·037	0·025
Protoxide of iron	0·82	0·64	0·45
Sesquioxide of iron	4·93	1·90	1·13
Alumina	10·16	13·22	4·32
* Lime	10·59	19·38	27·16
	No. 69.	No. 70.	No. 71.
* Equal to Carbonate of Lime	18·92	34·62	48·51

Analyses.	No. 69. Red marl.	No. 70. Grey marl.	No. 71. Red band.
* Magnesia	8·96	7·60	18·52
Potash..........................	0·76	0·13	0·42
Soda	0·12	0·02	0·09
Sulphuric acid	none.	none.	0·13
Carbonic acid and loss	15·86	22·763	36·765
Insoluble siliceous matter :—			
Silica .... 36·72		26·54	
Alumina................ 4·35		2·83	
Lime .... 0·15	43·51	0·30	30·34 9·26 mostly Silica.
Magnesia.............. 0·43		0·23	
Oxides of iron ...... 0·53		0·36	
Alkalies and loss ... 1·33		0·08	
	100·00	100·00	100·00

In this section the change of colour seems to have been brought about by a combination of mechanical and secondary causes. The amount of iron decreases upwards from the red to the grey beds ; but the curious freckled disposition where the grey and red colours inter-lace is evidently *not* the result of sedimentary arrangement, and ap-pears to be connected with the infiltration of lime from the overlying calcareous bands, and a secondary bleaching of a uniformly red bed. Fig. 16 (Pl. XII.) represents a section of some Permian strata in a cutting of the Severn Valley Railway, between Linley and Bridg-north, including red marls overlain by a calcareous band, in contact with which the red marls have been discoloured of an ochreous grey ; the interlacing disposition of the yellowish grey and the red, with an irregular boundary of separation, shows that the former is a secondary product of the original uniform red colour.

The composition of the red marl (Analysis No. 4, by Dr. Voelcker) is as follows :—

Water of combination	2·79
Sesquioxide of iron	3·23
Protoxide of iron	1·35
Bisulphide of iron	0·02
Carbonate of lime	4·15
Sulphate of lime	0·17
Alumina	3·95
Magnesia	2·17
Alkalies and loss	1·22
Matter (exclusive of the iron) insoluble in hydro-chloric acid	80·95
	100·00

The composition of the ochreous yellow marl (Analysis, No. 3, by Dr. Voelcker) :—

Water of combination	1·38
Sesquioxide of iron	6·482
Protoxide of iron	0·309
Sulphur	0·039

	No. 69.	No. 70.	No. 71.
* Equal to Carbonate of Mag-nesia	14·40	14·36	28·43
and Magnesia in a state of silicate	2·10	0·76	4·41

Carbonate of lime	35·58
Magnesia	0·91
Alkalies and loss	0·35
Alumina.....................	2·44
Matter (exclusive of the iron) insoluble in hydrochloric acid	52·51
	100·00

The principal difference in the composition of the red and ochreous portions consists in the presence of a large proportion of carbonate of lime in the latter, which has evidently been infiltrated from the overlying calcareous band, accompanied by a change to the colour prevailing in the more calcareous parts of the Wenlock shale. In this case, however, there is no increase in the proportion of protoxide to sesquioxide of iron. The yellow colour of the Magnesian Limestone lying in the midst of red beds, may perhaps be an analogous case; and the entire absence of red beds from the calcareous Oolites must also be noticed; it is clearly independent of the amount of iron present, as nearly all the grey and yellow beds of the Oolites (see analyses Nos. 64, 65, 66, p. 357) contain similar proportions of iron to those in the various red beds.

Although an increase, from extraneous sources, of the calcareous element in any red bed seems to induce bleaching and discoloration, it does not bear a perfectly regular ratio to the proportion of lime present, as discoloration has taken place in some red beds connected with the infiltration of a less amount of carbonate of lime than that originally present in others that have not been so changed, and a blood-red colour pervades the base of the chalk at Hunstanton. It may, however, be generally stated that a bright-red colour is a character of non-calcareous strata, and dun-colour, or grey, of calcareous beds, quite irrespectively of the amount of iron present.

I will not attempt any explanation of these facts, and merely offer them as worth further investigation, and requiring a larger series of observations before any reliable conclusions can be suggested.

11. *On the Condition of the Iron in the Depleted Areas of Red and Purple beds.*—Before leaving this part of the subject special reference must be made to the circumstances attending the colour and state of combination of the iron in the buff and green blotches of slates and red beds. It is important to bear in mind that their colour bears no definite relation to the proportion of the iron which they contain. As a rule the blotches contain a much smaller proportion of iron than the red, purple, or blue ground on which they are disposed; but whilst a certain proportion of iron may form the colouring base of one red bed, it may contain actually less than the light blotches on another; and, furthermore, the great bulk of the iron may in each case be in a state of sesquioxide; so that the mere abstraction of a part of the iron will not by itself explain the local reduction of the red colour to a paler hue.

The discoloured blotches vary in tint from a light clear sea-green

to an ochreous yellow. Although these extremes are not very distinct, and are connected by a series of gradations of intermediate shades of colour, they are evidently due to independent causes. There seems to be no uniform relation in the proportion of silicate of iron in the light and dark parts of variegated beds; and its amount seems to vary independently of the action of discoloration. The protosilicate is probably the colouring principle of the blotches tending to green. Bischof (Chemical and Physical Geology, vol. ii. p. 130, English edition) also records the occurrence of this green protosilicate in variegated sandstone which had no green colour. In association with sesquioxide of iron, the green-colouring power of the silicate would be obscured, but developed on the removal of the red sesquioxide. This, we have seen, has taken place in every degree; and where the segregating motion of the red anhydrous sesquioxide has occurred, it has generally become hydrous. The hydration of itself, without any diminution of the sesquioxide, would produce a lighter yellow blotch on the red ground; indeed, in the red clays of the Lower Bagshot beds, a yellow clay occurs, lighter in colour than the red, though containing more of the sesquioxide of iron, and rendered lighter simply by its becoming hydrous.

The following are analyses of the red and yellow portions of the variegated clay represented in fig. 23, Pl. XIII.

Analysis No. 33. Blood-red clay, Lower Bagshot beds. Messrs. Pike's Clay Works, Wareham. (Dr. Voelcker.)

Sesquioxide of iron with traces of protoxide ... 5·28 per cent.

Analysis No. 19. A second specimen of bright-red clay, Messrs. Pike's Clay Works, Wareham, Lower Bagshot beds. (Laboratory of the Museum of Practical Geology.)

Total iron	{	Soluble.................	2·061	} 2·52 per cent.
	{	Insoluble	0·459	
Present as	⎰	Sesquioxide of iron	2·944	„
	⎱	Protoxide of iron, soluble ...	traces.	
		Oxides of iron, insoluble,		
		weighed as protoxide	0·590.	„

Analysis No. 20. Bright ochreous yellow clay, intermixed with No. 19. Lower Bagshot beds, Messrs. Pike's Clay Works, Wareham. (Laboratory of the Museum of Practical Geology.)

Total iron	{	Soluble.................	5·382	} 5·743.
	{	Insoluble	0·361	
Present as	⎰	Sesquioxide of iron	7·69,	
	⎱	Protoxide, soluble	a trace.	
		Oxides of iron, insoluble,		
		weighed as protoxide	0·465.	

The variegation of the Horderley (Caradoc) sandstone, fig. 28 (Pl. XIV.), in which green bands and blotches occur on a purple ground, appears only accountable by the further hydration in patches of the sesquioxide of iron to which the purple colour is due.

The following determinations of the iron in the purple and green portions fail to afford any other explanation, as they contain identical amounts of sesquioxide.

Analysis, No. 87, by Dr. Voelcker. Purple portion, Horderley sandstone, Horderley, Shropshire.

	Water of combination	0·42 per cent.
Soluble {	Protoxide of iron	1·11
	Sesquioxide of iron	3·51
	Alumina and other constituents soluble in hydrochloric acid ...	2·47
	Insoluble siliceous matter containing oxides of iron, weighed as sesquioxide 1·055............ }	92·49

100·00

Analysis No. 88, by Dr. Voelcker.   Green portion.

	Water of combination	1·29 per cent.
Soluble {	Protoxide of iron	2·48
	Sesquioxide of iron	3·51
	Alumina and other constituents soluble in hydrochloric acid	5·37
	Insoluble siliceous matter containing oxides of iron, weighed as sesquioxide 0·668 .... }	87·35

100·00

In the green part of this example there is an excess of protoxide, compared with that in the purple, without a corresponding diminution in the soluble sesquioxide, though the total amount of iron is nearly equalized by the excess of insoluble oxides of iron in the purple.

There are, therefore, two distinct causes operating together in determining the colour of the pale blotches in red beds and slates—first, the *exposure* of the pre-existing green protosilicate by the partial or entire removal of the red sesquioxide, and, secondly, the conversion of any remaining anhydrous sesquioxide into the hydrous form.

The higher silicates, which tend to a yellow colour, may also be in part the colouring-matter of the depleted blotches. Their separate determination in the analyses has not been attempted; and it is sufficient for my present purpose to observe that they are numerous, that their constitution varies with their occurrence, as double silicates with lime, magnesia, &c., and that their colours range from green to yellow.

12. *On the Ferruginous Banding of Yellow Sandstone.*—Another form of variegation, distinct from those before referred to, is seen in the arrangement of hydrous sesquioxide of iron in yellow strata, as bands and fields of colour disposed unconformably to the stratification.

That this ferruginous banding is independent of the original mechanical arrangement is obvious; and the question it suggests is, whether the variegation results from the infiltration of the iron on to a light ground, or from a rearrangement of the yellow sesquioxide originally pervading it.

In some cases, as in fig. 53, the disposition of the ferruginous lines bears a resemblance to the way in which a coloured liquid stains and pervades an absorbent body (for example, stains of coffee

on a linen cloth), the circumference of the patch being darker than the general mass, and drying up to a hard line against the unstained

Fig. 53.—*Carboniferous Sandstone, with Ferruginous Bands, Workington, Cumberland.*

portion. I believe the similarity is only resemblance, and that a careful examination of the whole of the phenomena presented by banded yellow rocks will lead to the conclusion that it is independent of any mechanical process.

One of the most suggestive points is the almost invariable contiguity of the lightest to the darkest parts of the strata. In some cases dark ferruginous bands are environed on either side by exceptionally light portions, which graduate into the general colour of the stone; but the most frequent arrangement is the bounding of the dark band on one side by white sandstone, and on the other by yellow.

On any view of mere mechanical arrangement it is impossible to explain this very constant phenomenon, as, if the ferruginous stain was infiltrated into a lighter-coloured rock, the presence of exceptionally light portions, *lighter than the average colour of the bed*, seems quite unaccountable.

Fig. 35, Pl. XV.*, and figs. 54 and 55, represent two of the simplest forms of this banding and blotching—figs. 35 and 54 consisting of isolated light patches on a uniform yellow ground, separated by a dark ferruginous ring, and fig. 55 of a yellow patch separated by a similar ferruginous band from the lighter ground on which it is placed. In this case the complete isolation of the dark areas of ferruginous colour excludes the possibility of their being due to foreign infiltration. Fig. 56 represents a somewhat similar form of variegation, occurring in the Ashdown sands (Wealden), near Hastings; and determinations of the iron in the light and dark portions, made at the Labo-

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* I wish to express my obligations to Mr. Allen for the very successful execution of Pl. XV. by the mezzotint process, which seems peculiarly available for the rendering of subjects with much variety of colour. The whole of the colours on this sheet were worked from two steel plates, with only two separate printings.

Fig. 54.—*Banded Yellow Rock, Northamptonshire Oolites.*
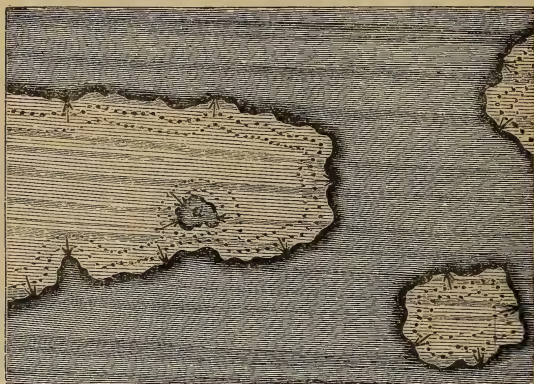
Fig. 55.—*Banded Sandstone, Grès des Vosges, near Raon l'Etape, Vosges.*

Fig. 56.—*Variegated Yellow Sandstone, Ashdown Sands, Hastings.*

ratory of the Museum of Practical Geology, gave the following re-
sults :—

Analysis No. 89.   Light ground, Ashdown Sands, near Hastings
(fig. 56).

Iron ... { Soluble in hydrochloric acid .... 0·130 } Total 0·225.
          { Insoluble .... 0·095 }

Present as Sesquioxide of iron .... 0·145
   ,,   Protoxide of iron .... 0·036
   ,,   Oxides of iron, insoluble, weighed as pro-
             toxide .... 0·122

Analysis No. 90.   Yellow portions of Ashdown Sands, near
Hastings (fig. 56).

Soluble in hydrochloric acid.................... 0·911 } Total iron 0·997.
Insoluble...................................... 0·086 }

Present as Sesquioxide of iron .... 1·260
   ,,   Protoxide of iron.......................... 0·037
   ,,   Oxides of iron, insoluble, weighed as
             protoxide .... 0·111

The dark area in fig. 56 contained therefore about four times the
amount of iron in the light; and the dark ferruginous band of sepa-
ration (of which no determination was made in this example) would
contain from 30 to 40 per cent of hydrous sesquioxide of iron.   The
position of the cracks, c, c, in relation to the darker area is strongly
suggestive of infiltration; and a somewhat similar arrangement of
ferruginous colour, in relation to lines of joints, occurs in the Car-
boniferous sandstone on the coast south of Whitehaven (fig. 57).

Fig. 57.—*Carboniferous Sandstone, coast south of Whitehaven.*
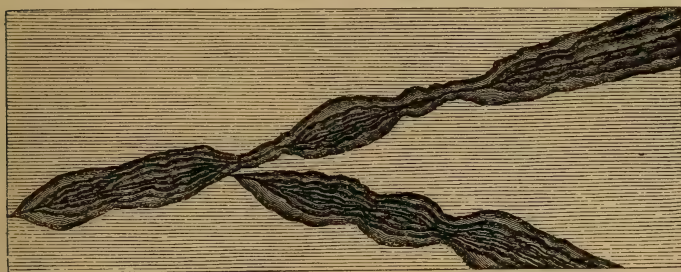
Some of the jointed rocks (fig. 58), however, on the same coast,
in which the disposition of the light and dark areas is evidently re-
lated to the joints, present the very reverse arrangement—the light
areas bounding the lines of joining, whilst the general yellow ground
occupies the intervening spaces.

Here, therefore, there appears to be the same kind of inter-
changeable arrangements of light to dark, and dark to light, as is
found in the other forms of variegation, the exhausted areas being the
result, not only of aggregation, but of dispersion, and corresponding
with the examples figs. 54 and 55, in which both an isolated depleted

area occurs on a darker ground, and isolated dark areas on a light depleted ground.

Fig. 58.—*Carboniferous Sandstone, coast south of Whitehaven.*

The arrangements of yellow banding generally occur quite irrespectively of the mechanical structure of the bed, the stratification being indifferently intersected by it. In other cases, variations of mineral structure seem to have influenced similar rearrangements of the oxide of iron, *e. g.* the presence of pieces of clay in the Ashdown Sands, Hastings (Pl. XV. fig. 33), having determined the aggregation of a shell of oxide of iron around them, accompanied by the bleaching of the surrounding sandstone. In another case, lenticular patches of sandstone in the midst of a more clayey bed has determined the aggregation of the ferruginous line to the point of separation.

In some parts of the Ashdown sands, at the foot of the East Cliff, Hastings (fig. 59), a further change has supervened, the connected banding having given place to the separation of the oxide of iron into small nuclei, the disposition of which faintly indicates the original continuous lines. Nearly all yellow strata coloured with the hydrous sesquioxide of iron give indications of these secondary changes. The Calcaire grossier (Pl. XV. fig. 34) is occasionally faintly banded; and wherever a line occurs darker than the general cream-coloured ground, it is invariably accompanied by an adjacent line somewhat lighter. Although these bands range with the stratification, they

Fig. 59.—*Ashdown Sands, Wealden, Hastings.*

can scarcely be due to mere mechanical alternation; and the darker accumulations seem to have resulted from the impoverishment of the adjacent bleached portions.

Whatever may have been the active agent which brought about these changes of position, the kind of motion which has rearranged the oxide of iron may be suggested by the facts before us. Instead of its direct accumulation into spherical nuclei as in most red beds, the separation seems to have taken place in lines which have advanced in one direction, leaving behind them the bleached sandstone deprived of its iron, and gradually gathering up the iron in its advance. This motion has sometimes taken place in the plane of stratification (Plate XV. fig. 34), and sometimes centripetally, either towards some mechanical nucleus, which it has ultimately environed and closed over with a ferruginous crust (Plate XV. fig. 33), or in the body of the homogeneous stratum, enclosing, as in fig. 55, p. 390, an isolated portion of the unaltered yellow sandstone. More rarely the motion has taken place centrifugally, the lines expanding from the series of centres (Pl. XV. fig. 35, and, *supra*, fig. 54), ultimately leaving isolated exhausted patches, circumscribed by spherical cakes of oxide of iron, and lying in the midst of the unaltered ferruginous matrix.

In the Wealden and Keuper sandstone these lines of segregation are often disposed with a very complex arrangement, one ferruginous band abruptly terminating at right angles to a horizontal or concentric series. The lines never cross each other ; and one series appears to have absorbed (as in fig. 36, Pl. XV.), and rearranged on its own line of disposition, the oxide of iron from the lines it superseded.

Fig. 60. — *Yellow-banded Carboniferous Sandstone, Benthall, near Broseley.*

There are cases, as in fig. 60, of banded Carboniferous sandstone at Benthall, near Broseley, in which a number of concentric lines of ferruginous segregation appear to have simultaneously advanced and closed in towards a centre, producing an alternation of brown bands of accumulation, and bleached bands of depletion, *the lightest and darkest parts being always in juxtaposition.*

Another point to be noticed is the occurrence, within the light areas of depletion, such as are represented in figs. 53, 54, 55, 58, and 61, of isolated patches of the unaltered yellow rock, circumscribed by the ferruginous line of accumulation. In these cases the ferruginous line bounding the mass of the depleted area is very sinuous, apparently from an irregular rate of advance at different points. The outer yellow ground may thus intersect the depleted area by deep bays (*b*, fig. 61) ; and these, by the continued irregular advance outwards of the absorbing line, may become isolated and left behind, like islands (*a*, fig. 61) in the depleted area. There is also another cause for this phenomenon ; the sinuous circumscribing line

of two neighbouring areas of depletion, in their centrifugal advance, will ultimately coalesce (as near the bottom of fig. 37, Plate XV.) at the first point of contact, and thus isolate portions of the yellow ferruginous ground, as in fig. 61, c, c.

Fig. 61.—*Direction of Line of Ferruginous Accumulation in banded yellow Sandstones.*

The further encroachment of the line of accumulation over the detached patch will then be convergent, though it is simply an uninterrupted continuation of the divergent course of the main line. This may perhaps help to explain the apparently opposite courses that the absorbing lines have taken under similar conditions; the kind of motion is the same in both cases, the uniform tendency being for the line of accumulation to advance *from the already exhausted area towards the unexhausted part, whether it be a centrifugal or centripetal motion.*

This yellow banding, represented in fig. 36, Plate XV., is so evidently connected with the contiguity of mineral veins, that it may be important to notice the precise manner of its occurrence. The Lower Keuper of Shropshire consists, for the most part, of light-buff sandstone, brown-mottled sandstone (fig. 40, Plate XV.), before referred to (p. 376), red sandstone, scarcely distinguishable from the underlying Bunter, and the curiously banded yellow sandstone, fig. 36 (Pl. XV.). These do not occupy distinct stratigraphical horizons. The red and buff series of rocks is vertically intersected by copper-lodes* of a bright sea-green colour, for the most part devoid of iron. The sandstone, which at a distance from the lode is red and buff, is, where it forms its boundary, charged with hydrous sesquioxide of iron, arranged in fine bands. The ferruginous lines end irregularly and abruptly against the lode-like mass of sandstone charged with copper, the boundary being generally defined by a thin brown line of hydrous sesquioxide of iron, into which the other ferruginous courses coalesce. The presence of this " corduroy rock " is looked upon by the miners as a sure indication of proximity to the copper; and as the lode is horizontally receded from, the sandstone assumes its ordinary red-and-cream colour.

Looking, then, at the fact that the light beds of the Keuper are both underlain and succeeded by great masses of red beds, and that they include isolated patches of red rock vertically disposed through their mass, and much iron in a variety of conditions and modes of arrangement on every horizon, their uniformly primordial red colour seems probable; and the evident connexion between the variegation

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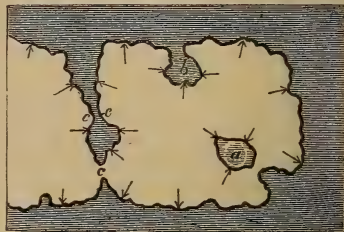
* These are not true lodes with a distinct filling to the matrix, but consist of the ordinary sandstone charged with from 1 to 5 per cent. of carbonate of copper, and containing also cobalt, manganese, baryta, lead, &c., the whole having a lode-like disposition vertically intersecting the adjacent rock.

of these beds and the occurrence of mineral veins may perhaps help to throw some light on the agency by which the rearrangement of the iron has been influenced.

Another peculiar form of variegation occurring in the Keuper Sandstone, and due to the secondary disposition of copper and iron, is represented in figs. 38 & 39, Plate XV., from the Alderley copper-mine, and consists in the segregation to distinct points, out of a common ground, of carbonate of copper and hydrous sesquioxide of iron. These examples give evidence of a dispersive as well as an aggregating action; for round each nucleus of copper there is a pale circumscribing zone from which the iron has been expelled. The iron appears also to have occupied particular centres, from which the copper has in like manner been driven, resulting in a singularly picturesque mottling of brown and blue blotches, with interspersed gradations of green and yellow.

13. *The Variegated Iron-ore Deposits of the Northamptonshire Oolites.*—In connexion with the subject of yellow-banded sandstones, reference must be made to the ironstone deposit of Northamptonshire, which illustrates with strongly marked features the same principle of arrangement. A position has been assigned to it both at the base of the Great Oolite and the top of the Inferior Oolite. The workable bed averages from 12 to 20 feet in thickness. Fig. 37 (Plate XV.) represents a portion from the neighbourhood of Blisworth, compiled from a sketch made on the spot, and some photographs kindly procured for me by my friend Mr. S. Sharp, F.G.S., of Dallington Hall. The whole stratum gives indications of having been completely rearranged since its deposition, even to the almost entire obliteration of its stratified structure.

Taking the bed *en masse*, it contains, averaging one part with another, from 25 to 40 per cent. of iron. It consists, for the most part, of a loose earthy friable ground of a bright-yellow colour, exhibiting an oolitic structure under the microscope. Its composition is as follows:—

No. 79. Analysis by Dr. Voelcker of a friable portion of the Northamptonshire iron ore, near Blisworth:—

Protoxide of iron	0·875
Sesquioxide of iron	21·280
Phosphoric acid	1·030
Sulphuric acid	0·219
Silica, lime, alumina, magnesia, &c,, not separately determined	76·596
Carbonic acid	none.

This was pervaded by hard ferruginous bands having, for the most part, a curious cellular arrangement, with the same disposition as the structure represented in fig. 54; but, instead of occurring at isolated intervals on the yellow ground, the entire mass of the stratum is made up of the box-like structures. From mutual pressure in close proximity they have assumed the forms of irregular cubes, sometimes elongated in harmony with the stratification, but occasionally, where a joint appears to have occurred, attenuated in a vertical direction. It is important to notice that the boundary of each cavity is independent

and complete in itself, so that the hard septa separating the cubes are *double,* and may generally be parted into distinct layers (fig. 62). The following determination of the iron was made by Dr. Voelcker.

Analysis No. 78, of hard ferruginous cakes and layers, Northamptonshire iron-ore deposit, near Blisworth :—

Fig. 62.—*Detail of Structure of the Oolitic Iron-ore formation, Northamptonshire.*

Protoxide of iron...............	1·352
Sesquioxide of iron	76·538
Phosphoric acid	0·020
Carbonic acid	0·014
Silica, alumina, lime, water, &c., not separately determined.	22·076
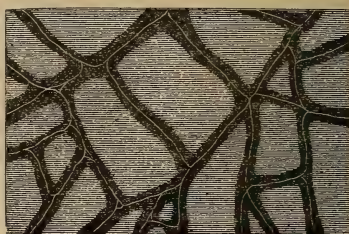
These bands of accumulation appear to have originated in the same way as the dark lines represented in fig. 54, p. 390, each having advanced from its centre until arrested by contact with its neighbour, mutual pressure against each other having determined the angular form of the ferruginous shells.

In addition to the yellow earthy ground forming the mass of the deposit, and occupying most of the cavities, two other conditions of iron are found. At about the middle of the bed occurs a line of grey nodules of compact carbonate of iron, each of which is environed by a cellular crust of the hydrous sesquioxide; their composition is as follows.

Analysis No. 76, by Mr. D. Forbes, of nodules of compact carbonate of iron (upper part of fig 37, Plate XV.). Iron-ore formation, Inferior Oolite, near Blisworth :—

Specific gravity 3·58.

Protoxide of iron...............	49·58	= 79·9 carbonate of iron.
Sesquioxide of iron............	5·67	
Bisulphide of iron	0·96	= iron 0·45, sulphur 0·51.
Protoxide of manganese......	0·16	
Alumina	1·56	
Lime	3·24	= 5·8 carbonate of lime.
Magnesia......................	0·46	= 1·0 carbonate of magnesia.
Carbonic acid	34·64	
Phosphoric acid	0·44	
Silica	2·16	
Organic matter	...	Trace.
Water of combination	1·56	

100·43

Still lower down, near the base of the deposit, are some green patches, likewise environed by a sinuous line of the brown ferruginous cake. Except in colour, they resemble in aspect and texture the general

earthy ground of the deposit, being made up of incoherent Oolitic grains. The following is their composition.

Analysis No. 77, by Mr. David Forbes, of green patches at base of Northamptonshire iron-ore deposit (fig. 37, Plate XV.).

Protoxide of iron	40·93
Sesquioxide of iron....	6·14
Protoxide of manganese	0·16
Alumina	8·08
Lime	3·47
Magnesia	2·21
Potash	0·19
Soda	0·27
Sulphur	trace
Carbonic acid	22·32
Phosphoric acid	1·99
Silica	9·04
Water	4·92
	——
	99·72*

The specific gravity at 60° Fahr. was found to be 3·401; and an examination by the microscope showed it to consist almost entirely of two mineral constituents—the one crystalline and colourless, being chiefly carbonate of iron, and the other of a green colour, probably silicate of alumina and iron. Whether the green colour is due to it or to the presence of phosphate of iron is not decided, but it appears probable that a green silicate does exist in the mineral.

It may be roughly estimated to consist of

    80 per cent. of carbonate of iron,
     7 per cent. of carbonates of lime and magnesia,
    $11\frac{1}{2}$ per cent. of silicates of iron and alumina with phosphoric acid,
and $1\frac{1}{2}$ per cent. of water.

It will be seen, therefore, that the composition of the grey nodules, and likewise of the friable green patches, is essentially different from that of the mass of the deposit, and, furthermore, that their isolated disposition excludes the possibility of a separate mechanical origin. The question then arises, whether any of the states of combination in which the iron now occurs in the bed, was its primordial condition, and which of the other conditions have been subsequently induced. The nodules of subcrystalline carbonate of iron forming the upper grey course are clearly of secondary origin, and appear to have been segregated out of the general mass; and the lower green patches do not differ much from them in composition, though retaining the original oolitic structure of the rock. Mr. Sorby (Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire for 1856–57, p. 457) has shown that, in the Cleveland iron ore of the Lias Marlstone, carbonate of iron has become substituted for carbonate of lime in fossil shells and oolitic grains; and it appears probable that these similar masses in the Northampton-

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* The composition closely resembles that of the Cleveland iron ore analyzed by Mr. Dick, and given at page 57 of the 12th volume of the Quarterly Journal of the Society.

shire beds are due to segregation, in which carbonate of iron has in like manner been drawn towards centres of aggregation, whilst the hydrous sesquioxide has been dispersed, in the form of receding bands, out of an original matrix containing both the carbonate of protoxide, and sesquioxide of iron in association. The phosphoric acid appears to have been nearly all aggregated with the carbonate of iron, scarcely any occurring in the brown cakes of sesquioxide; and the carbonic acid has also been almost entirely withdrawn from the brown bands and general mass of stratum to the centres of aggregation of the protoxide of iron. It may here be noticed that concretions of carbonate of iron, wherever occurring, invariably present the uniformly homogeneous structure * observed in those of the Northamptonshire beds, whilst nodules of sesquioxide of iron are characterized by a concentric banding, such as would be the result of successive accumulations of the concentrating lines observed in yellow-banded sandstones (fig. 60, p. 393).

Kernel-roasting.—The artificial process known as "kernel-roasting" of copper ores presents some phenomena so closely resembling the mode of aggregation of the oxides of iron in yellow-banded sandstones, that a brief reference to it may not be inapplicable as illustrating the kind of motion which the iron appears to have taken. A full description will be found at p. 349 of 'Percy's Metallurgy,' from which the following is abridged. When cupriferous iron pyrites containing, say, from one to two per cent. of copper, in lumps about as large as the fist, is subject to a very gradual roasting at a low heat with access of air, it is found that a large portion of the copper becomes concentrated in the centre of each lump (fig. 63†).

Fig. 63.—" *Kernel-roasting* " *of Copper Ores.*

In the early part of the process, a lump broken across (*a* and *b*) consists of a central mass of unchanged ore, enclosed in a shell of a reddish-brown substance like sesquioxide of iron; and between the two is interposed a thin, more or less continuous layer containing more copper than the original ore. At about the middle of the roasting, several such concentric layers may be observed; and when the process is further advanced, a nucleus of unchanged ore can no longer be seen, the outer brown crust becomes greatly increased, and the concentric stratification of the copper layers is still visible.

* Merely as regards the absence of banding, as subsequent brecciation has frequently produced complex modifications in the original structure.
† For the use of this engraving I am indebted to the kindness of Dr. Percy.

DISPOSITION OF IRON IN VARIEGATED STRATA.

Anhydrous Sesquioxide of Iron.

Hydrous Sesquioxide of Iron.
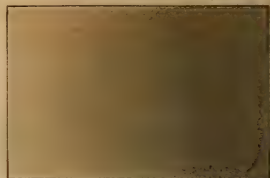
Carbonate of Protoxide of Iron.
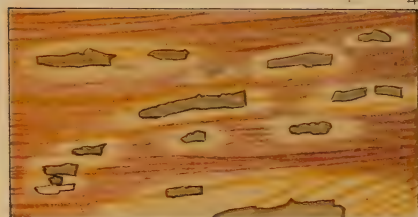
⅕ Grès bigarré, Trias, Baccarat, France.

⅗ Red Beds N.ʳ Torquay, S. Devon.

⅗ Grès des Vosges, Near Raon l'Etape, Vosges.
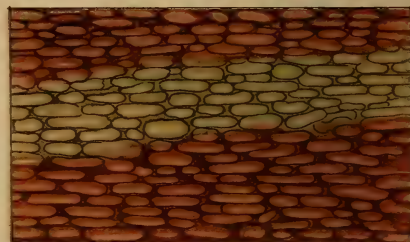
¼ Pebble Bed in Carboniferous Limestone, Trevor, n.ʳ Llangollen.
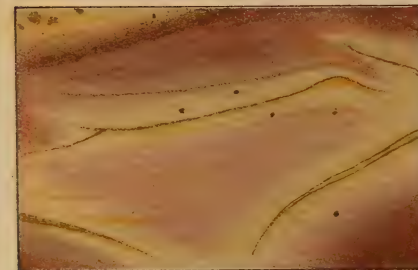
⅗ Permian, Kemberton Pits, near Madeley, Salop.
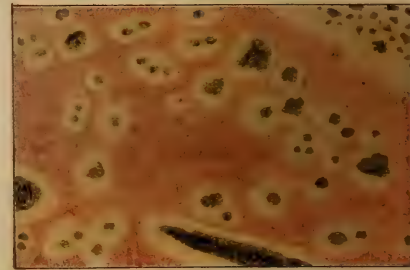
⅕ Permian, Coalport, Shropshire.

3/10 Keuper Sandstone & Marl, Alderley Copper Mine, Cheshire.

1/15 Keuper Sandstone & Marl, Alderley Copper Mine, Cheshire.

12

$\frac{1}{12}$ Grès Bigarré, Trias, France, Stone in basement of Palace of Industry Paris.

13
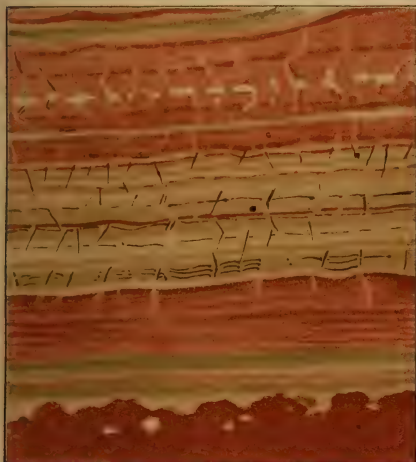
$\frac{1}{30}$ Keuper Marls, Worcester Station.

14

$\frac{1}{20}$ Old Red Sandstone, Kerriemuir Forfarshire.

15

$\frac{1}{40}$ & $\frac{1}{2}$ Marnes irisées, Trias, Enville Lunéville, France.

16

$\frac{1}{40}$ Permian Marls, Railway Cutting near Linley Shropshire.

DISPOSITION OF IRON IN VARIEGATED STRATA.

17
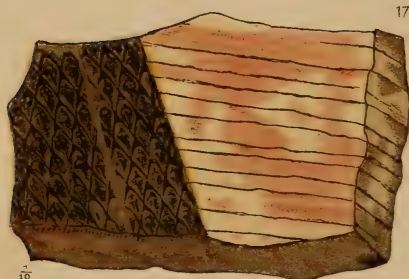
Environs of Ardenav, Marne et Loire,
Museum of Jardin des Plantes, Paris.

18

Terrain houiller, Sarrebrück Museum of
Jardin des Plantes, Paris.

20   21
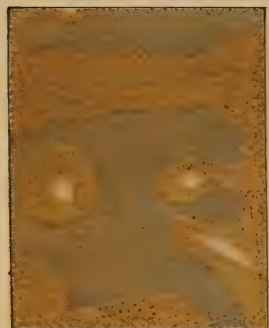
19

$\frac{1}{5}$ Great Oolite, Kingsthorpe,
Northampton.

$\frac{1}{5}$ Marl under Glaises-Vertes,
Butte-Chaumont, Paris
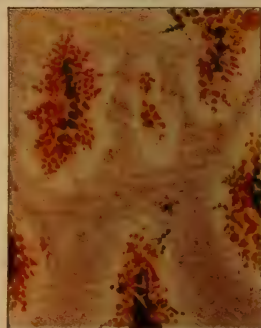
$\frac{2}{3}$ Argile Plastique, Vaugirard,
Paris   23

22
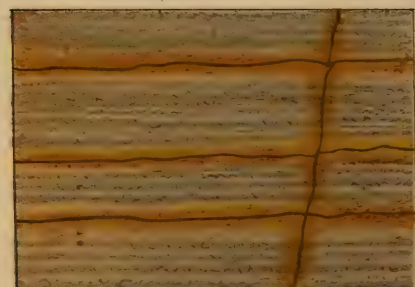
$\frac{7}{10}$ Upper Purbek Marble, Woody-Hyde, Swanage
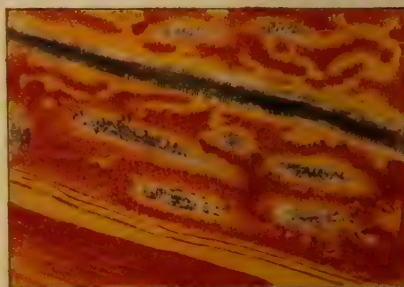
$\frac{1}{5}$ Lower Bagshot Clays, Nr Wareham.

24   25   26
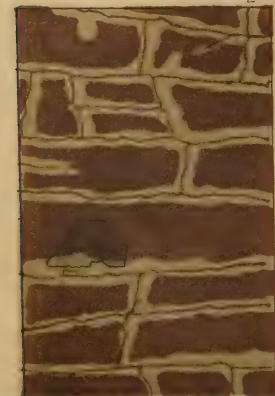
$\frac{1}{8}$ Cambrian, Bayston Hill, near
Shrewsbury.
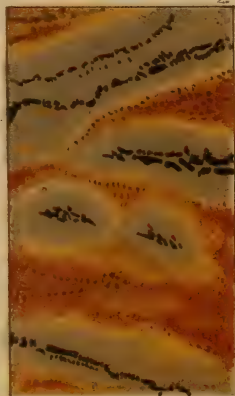
$\frac{1}{5}$ Surface Clay, Benthall,
Shropshire.

$\frac{1}{10}$ Lower Green Sand,
West of Folkstone,

27. Carboniferous, Railway Cutting nr Bewdley, Worcestershire.

28. Caradoc Sandstone, Horderley, Salop.
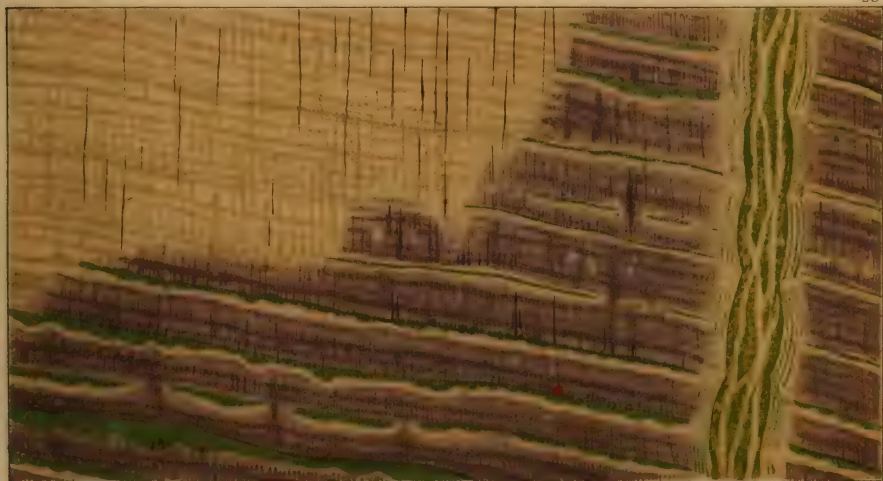
29. Banded Cambrian Slates, with intrusive dyke of Diabase, Carnarvonshire.

30. Lower Silurian? Head of Crummuck Water, Austwick, near Clapham, Yorkshire.

31. Cambrian Slate. Penrhyn Quarries.

32. Cambrian Slate. Glynn Quarries, Llanberis.
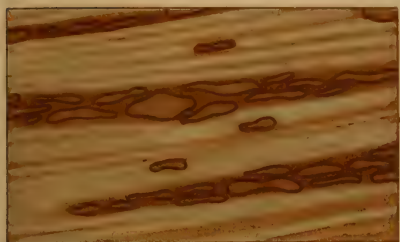
Ashdown Sands. Wealden.
Hastings.

Calcaire Grossier Chaville Railway
Station near Paris.

Horsham Stone Wealden.

Keuper Sandstone. Clive Copper Mine.
Shropshire.

Iron Ore formation. Inferior Oolite.
Northamptonshire.
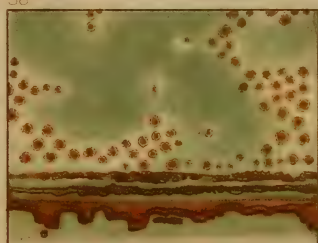
Cupriferous Keuper Sandstone.
Alderley, Cheshire.
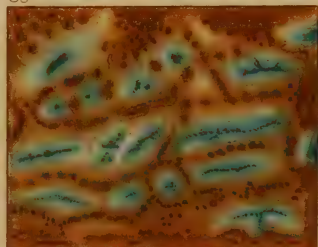
Cupriferous Keuper Sandstone.
Alderley. Cheshire.
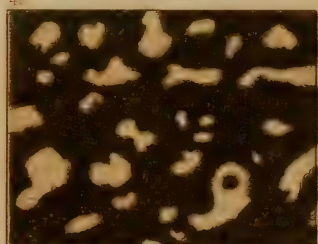
Keuper Sandstone, Clive-Hill,
Shropshire.

In the last stage (*c*) the concentric arrangement disappears, and the great bulk of the copper is accumulated as a central nucleus in the condition of rich copper regulus. In large lumps several such nuclei may be formed.

The various chemical changes taking place in the several stages, which have been investigated by Lürzer, are fully described by Dr. Percy; but a satisfactory explanation of the *character of the motion of the copper towards a central nucleus* seems wanting. It cannot be the result of the mechanical aggregation of fused particles, as the heat is not carried nearly to the melting-point, or even to plastic fusion; indeed the action is arrested beyond a certain temperature, and concentration is not the only phenomenon.

Mr. D. Forbes states that when silver is present in the ores, it appears to *travel outwards*, and that he has seen some specimens in which the outer surface of the piece of roasted ore was covered by a thin shell of metallic silver, as if electro-deposited. The phenomena, if not analogous, bear a curious resemblance to the kind of changes which have taken place in the Northamptonshire iron-ore beds, in which the protoxide of iron, and phosphoric and carbonic acids, have been aggregated towards definite centres, whilst the sesquioxide has been repelled from such centres in concentric ferruginous bands, travelling outwards until arrested by mutual contact.

I believe that many of the phenomena connected with banded agatescent and other concretions will be found analogous in character to these phenomena, and to the ferruginous banding of yellow strata—their accumulation having taken place in convergent or retrogressive lines within a solid matrix, producing a structure resembling the mechanical superposition of successive coats.

14. *Disposition of Manganese in Variegated Strata.*—Another case of secondary variegation, resembling, though independent of, the occurrence of iron, which may here be noticed, is represented in fig. 64, of sandstone and grit occurring at the base of the Shropshire Coal-measures. The black fields of colour are due to sesquioxide of manganese: they vertically intersect successive beds of conglomerate and sandstone; and their disposition is obviously due to some cause independent of mechanical arrangement, analogous to the forces that have operated in the rearrangement of iron.

Fig. 64.—*Carboniferous Grit and Sandstone, Willey Park, Shropshire, containing Black Oxide of Manganese.*

15. *General conclusions.*— In comparing the composition of the different coloured areas of variegated strata, one of the most

striking points is the very small proportion of the numerous forms of variegation that can be accounted for by the mere altered state of combination of the iron *in situ.*

The occasional conversion of the red anhydrous sesquioxide, or the lower hydrates, into fully hydrous sesquioxide, the reduction of sesquioxide to protoxide of iron in the production of green slates, and the exceptional cases of the alteration of colour of red beds by the decomposition of bisulphide of iron complete the list of colour-alterations by simple chemical change.

Even the agency of organic matter in inducing chemical changes in the state of combination of the iron, will not in most cases account for the bleaching—the segregational motion of the colouring oxide, which is the ultimate cause of the variegation, being supplemental to the simple chemical changes of combination.   The great majority of cases of variegation are independent of altered combinations, and more often than otherwise seem to have been induced by agencies not directly connected with chemical change. The transference of the colouring oxide from one part of the stratum to another has taken place by the simple mechanical agencies of infiltration and dissolution, as well as by segregation; but the latter, above all other agencies, has played the largest part in the variegation of ferruginous rocks.

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2. On the OLDER ROCKS of SOUTH DEVON *and* EAST CORNWALL*.   By HARVEY B. HOLL, M.D., F.G.S.

[Plate XVI.]

CONTENTS.

I. INTRODUCTION.

IN the course of last year I made an examination of the older rocks of South Devon and the adjacent portions of Cornwall, for the purpose of ascertaining the stratigraphical relations of the different beds, or groups of beds, with a view to their coordination with the more complete and better-known series in the northern part of the county. I was led to undertake this in the belief that, notwithstanding the many memoirs that have appeared on Devonian Geology, there was still a very great difference of opinion among geologists respecting

* This memoir is illustrated by an Ordnance Map coloured geologically, from which Pl. XVI. has been reduced.

the relations of the beds on the south side of the Culm-measures ; and any one who is acquainted with the literature of the subject will, I think, admit the fact.   Indeed the late Sir Henry De la Beche, subsequently to his last essay in the first volume of the Memoirs of the Geological Survey, regarded the succession of the rocks as still unravelled, and expressed his intention of taking an early opportunity of revising this portion of his labours*.

Many of the difficulties which stood in the way of the pioneers of Devonian geology have long since been cleared away, more especially by the publication of the Geological Survey-maps of Devon and Cornwall, the general accuracy of which is all the more remarkable as it was the first attempt at anything in equal detail in this country ; and a great step was made towards a better understanding of the structure of the Devonian country when Prof. Sedgwick and Sir Roderick Murchison, in identifying the Culm-measures with the Carboniferous system, separated them from the underlying slaty rocks with which, under the name of Grauwacke, they had been previously united†.   Nor need the general order of succession, as established by them thirty years ago, in the first of their memoirs, be greatly disturbed.   But there are many matters of detail, not comprehended in their memoir, which are still open to inquiry, notwithstanding the elaborate and able report subsequently published by the Geological Survey‡.   To this work the following communication must be regardedj as supplementary, its object being to enter, in a general manner only, on the consideration of certain points in the physical structure of that portion of the country which lies to the south of the Carbonaceous rocks of Central Devon and adjacent parts of Cornwall.

II. Carbonaceous Rocks or Culm-measures.

The Culm-measures, as they occur on the southern side of the great synclinal trough of Central Devon, consist of argillaceous slates, with seams of grit and chert, and include beds of volcanic ash and limestone, the latter for the most part of dark colours.   These limestones are precisely similar to those at the northern edge of the trough, near Bampton and South Molton ; and the grit and chert beds resemble those of Coddon Hill ; but the interstratified volcanic rocks, which are not met with in the north, occur here in considerable abundance ; and as they are likewise abundant in the underlying

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* See Sir Charles Lemon's Presidential Address, 1848.   Trans. Roy. Geol. Soc. of Cornwall, 35th Annual Report, p. 13.

† Trans. Geol. Soc. 2nd ser. vol. v. p. 633.   This first great reform in the classification of the rocks of Devonshire was made by Professor Sedgwick and Sir Roderick Murchison in 1836, and was communicated to the British Association in that year at Bristol.   See Report of British Association 1836, Proc. of Sections, p. 95.   All geologists, including Sir H. De la Beche, had previously considered the whole of the great Carboniferous tract of Devon to be part, and even a lower part, of that Grauwacke series which Sedgwick and Murchison assigned to the true Devonian, and which they had proved to underlie, and be wholly distinct from, the Culm strata.   See also Trans. Geol. Soc. 2nd ser. vol. v. p. 701., where the term Devonian was proposed.

‡ Geological Report on Cornwall, Devon, and West Somerset, p. 56 *et seq.*

Devonian rocks, they give to the two formations a general facies more similar in the southern than in the northern part of the county; and their separation is consequently more difficult. But although much of these slaty rocks bears a strong resemblance in lithological character to those of the underlying series, and occasionally gives rise to much perplexity in deciding to which system particular portions should be referred, nevertheless they differ as a whole in a manner which is sufficiently obvious, but which it is difficult to convey in words. For instance, the underlying rocks along the southern border of the Culm-measures are almost entirely devoid of grits, and consist essentially of fine argillaceous slates, more or less mixed with volcanic matters, and often much affected by cleavage. The higher series, on the contrary, is distinguished more particularly by the thin seams of greenish-grey grit, varying from half an inch to 2 or 3 inches in thickness, which they contain. These grits sometimes become locally more developed, and then constitute beds of greenish or greyish sandstone of considerable thickness, separated only by thin seams of slate; while in other places the thin grits are represented by thinly bedded black, or black and white, chert interstratified with dark-coloured slate, both the chert and the slate having a tendency to become bleached in weathering. Carbonaceous matter is not by any means so generally distributed, nor so characteristic as might be expected; and cleavage, although not absent from the more purely argillaceous portions of the series, is not so frequent as in the lower rocks.

The southern limit of these Carbonaceous rocks ranges from the coast at Boscastle by Lesnewth to Hallworthy, and thence along the south side of Laneast Down, and the north of Trewen, to a north and south fault, which crosses the Launceston turnpike-road west of Kenners House, and is laid down in the maps of the Geological Survey. This fault throws down the Culm-measures on the eastward, and brings the line between them and the underlying slates southwards to Congdon. From Congdon the line passes by Bolathan to the north side of the brook at Does Houses, where a few beds of slate separate the Culm-measures from the northernmost of the three Petherwin limestones. The Culm-measures dip to the north, and preserve this dip, undulating at angles which vary from 5° to 15°, to within half a mile of Launceston, where it becomes reversed. A little further down the stream, on its north side, on the road from Launceston to Landlake, there is a quarry of dark-blue or nearly black slate, with thin seams of grey grit. The slates contain *Posidonomya*, and dip south at from 5° to 10°. On the opposite side of the brook are the fossiliferous grey slates overlying the limestone which has yielded the rich but peculiar Cephalopod fauna of Landlake. Both the slates and the limestone dip N. 30° E., at an angle of about 20°; while the Culm-measures dip towards them with a lower but somewhat undulating dip. A quarter of a mile, or rather less, to the S.S.E. of the limestone, black chert is quarried in a field on high ground, dipping E. 25° S., at a low angle, with much contortion; and a little further down the brook similar beds are exposed near the bridge under Hardow Down, overlain by dark-grey flags with plant-

remains. These beds rise gently towards the south; but the chert
is much contorted. Yellowish or greenish Culm-measure sandstones,
with plant-remains, are also seen in a small roadside excavation
half a mile to the south-east of Hardow Down, opposite the turn-off
to Burdown, dipping S. 40° E.   From this place the line of junction
between the two formations passes in a southerly direction to near
St. Lavers; but a small outstanding patch of chert occurs in a field a
little south-east of Trewarlet, resting upon slates which contain fos-
siliferous seams, which appear to be on the horizon of the Pether-
win beds.   These slates dip due south, while the chert in the field dips
south-west at a low angle, and is underlain by thin grey grit exposed
near the entrance to the field.   Beyond the slates, and about half-
way between the chert-quarry and St. Lavers, the lane is crossed by
a fault running N.E. and S.W., which brings down a narrow strip
of Culm-measure slate and grit, together with some calcareous vol-
canic ash, dipping S.W.   On the south side of the little stream, how-
ever, we almost immediately come to pale-green slates belonging to
the underlying series, dipping S. 20° E. at a rather high angle; and
this dip is continued to beyond Lezant.

From St. Lavers the line passes south of Landue Mill, and across
the Callington turnpike-road, in a south-easterly direction, at a spot
where unconformability is noticed by Sir Henry De la Beche* (but
which in reality is a line of fault, as his sketch clearly shows), and
thence on towards Lowley Bridge.   Before reaching Cudducombe,
however, we again find Culm-measure slates and grits, the line be-
tween them and the underlying rocks recrossing the turnpike-road
to Trekenna, whence a long narrow strip of Carbonaceous rocks runs
along the northern slope of the ridge which extends from East Pen-
rest to beyond Trebollets. Along this narrow strip the chert, which is
well exposed in the quarries opened for road-stone, is for the most part
white, and dips north-east; but the bedding is much contorted, and
southerly dips occur lower down in the valley.   On the high ground
south-east of Lazant, near a place marked " Ruins" on the Ordnance
Map, coarse thick slates are exposed in a roadside-cutting; but I could
not satisfy myself whether they belonged to the Culm-measures or to
the underlying series.

Descending the hill from Cudducombe to the Inny river, either by
the Callington turnpike-road or by the lane which leads to Trehing-
stow, we pass over dark-coloured slates with thin grey grits dipping
S. 20° W.   These beds cross the river below Trecarrel Bridge, and
are separated from the volcanic ash on the south side of the stream
by a very inconsiderable thickness of the lower slates, as seen in the
section on the road from the bridge to Linkinghorn; but unfortunately
the actual contact is obscured by rubble.   At Tregvis the beds dip
S. 20° E., but halfway thence to Lower Trelabe they dip N. 25° E.
at 5°.   Between these two places occurs the axis of a synclinal
trough occupied by Culm-measures, which here consist chiefly of
slates, often of dark colour, and thin grey grits, with one or two in-
considerable bands of volcanic ash near Congdon.   These beds run

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* Rep. p. 107, and woodcut.

up by Coades Green, Congdon, and Trevadlock, and by the north of
Nighton nearly to Alternan.   The lowermost beds here appear to be
argillaceous ; and although sometimes black, as at Trevry, Trevadlock,
and Trevage, they are liable to become whitened, or of a very pale
colour, from exposure, and are then sometimes difficult to separate
from the underlying rocks.   North-east of Nighton the grey grits
have been quarried at the edge of a wood near the turnpike road,
where the beds dip N. 20° W. at 15°, and are in the same mineral
condition as at Trelabe, and on the banks of the Inny below Trecarrel
Bridge ;   and   in   some of the beds   plant-remains are numerous.
All the high ground on either side of the turnpike-road from the west-
ward of Alternan to Coades Green is capped with these beds, the
grits weathering to a greenish yellow colour, and becoming whitened
on the surface, and the slates becoming pale and soft, and then so
much resembling some of the underlying series that it is difficult to
distinguish them lithologically.   Near Trelask House there is a small
off-standing patch of the Culm-measures dipping E. 10° N., overlying
the ash-beds of Lawannick ; and two other outliers occur on the
opposite side of the Inny :—the one on the west of Pollinny, where
the beds dip north-east, and rest on slates that contain *Spirifera dis-
juncta* and other fossils ; the other to the south of that place, occupy-
ing the high ground on either side of the road to Larnick, with a
dip a little to the east of south.

Lower down the Inny these beds are well exposed at Beals Mill,
where they contain *Goniatites, Orthoceras,* and plant-remains, as
noticed by Professor Phillips ; and they include the grits of Mount
Pleasant and Inny Foot, which are continued past the Swiss Cottage
and Twowell Down towards Lammerton.   These beds dip southerly,
but, as they undulate on their line of strike, they deviate occasionally
by 25 to 30 degrees from due south.   Thus at Tregarvis the dip is
S. 10° E. ; at the New Bridge over the Inny on the Callington Road
it is S.S.W. ; at Beals Mill it is southerly ; at Inny Foot S. 10–20°
E. ; while at the Swiss Cottage it is S. 35° W.   This southerly dip
is continued across the Inny for at least half a mile ; but south of
Tregvis, Norton, and Kingston the dip is reversed, and about Pen-
pill we reach the southern limits of the Culm-measures, with the
exception of an outlier which caps the high ground between Linking-
horn and Southhill.

From Penpill the line which limits the Culm-measures on the
south follows the ridge of high ground by Venterdon and Stoke
Climsland to Lidwell, and thence nearly to Horse Bridge.   At the
crossroad north of Stoke Climsland there are some black slates with
chert bands, partly weathered white on the surface ; and similar Car-
bonaceous slates, partly blanched from exposure, are seen half a mile
to the north of this place on the road to Beal's Mill.   These are fol-
lowed by dark slates with grey grits quarried at Lower Down House
and Row Down, similar to those of Lawannick Down and Tregvis.
In descending the hill to Horse Bridge we pass from these dark slates
and grits with a northern dip on to grey roofing-slates, dipping appa-
rently to the west.   These underlying slates, with the same westerly

dip, are also seen in the river above the bridge, and in a slate-quarry on the opposite side of the river.   But a little further up the stream, opposite a place called Bridge Farm on the map, horizontal beds of dark-grey micaceous sandstones with carbonaceous slates occur, occupying lower ground than the roofing-slates in the lane ascending from the bridge to the quarry.   These Carbonaceous rocks set in immediately beyond the copper-lode which has thrown them down on the north.   The grits contain plant-remains, and resemble very closely those exposed at Lower Down House, west of Beal's Mill, and in the quarry north-east of Nighton.   This copper-lode forms the southern limit of the Culm-measures all the way to Hartwell, beyond which the line of their outcrop curves northward with the high ground to Chipshop and Ottery.   Westward of the latter place Carbonaceous slate with chert is seen in nearly horizontal position, although much contorted, while close by, in the adjoining field, the grey roofing-slates of Mill Hill quarry dip E. 40° N. at high angles.   From the northern side of this quarry the Culm-measures are continued to Stiles Wick and Downhouse Farm, and thence, thrown down by a fault, they cross the Tavy at the southernmost of the three bridges at Tavistock to Challicot; but they are difficult to follow across Whitechurch Down from want of exposures and, as we approach the moor, from the alteration in the mineral character of the rock produced by the granite *.   The Culm-measure slates with their thin grits are well seen in the bed of the river between the bridges at Tavistock when the water is low ; and chert is quarried near the town and in the vicinity of Collytown, on the road to Merriville Bridge.   These rocks are exposed also in a small section at the south end of the railway-station ; and the black slates have been cut into in lowering the roads on the west of the town.   A little north of the railway-station thick-bedded grits dipping north-west are faulted against a bed of highly calcareous volcanic ash dipping in the opposite direction.   Westward of this is an anticlinal axis followed by a synclinal trough, which runs in a north-easterly direction by Tavytown, south of which the Culm-measures crop out on Whitechurch Down.   The volcanic rocks, as they rise to the south on Whitechurch Down, consist chiefly of what appears to be compact chlorite with grains of quartz, and dip N.N.W. at an angle of 30°.   The town of Tavistock lies in a synclinal trough running north-east and south-west.   The rocks are much disturbed and contorted, and there are many small faults in the vicinity of the town.

At Pentre Cross, near St. Mullion, several miles to the south, there are two small outlying patches of these Culm-measures brought down by an east and west fault, with a downthrow on the north, which crosses the turnpike road a little south of the turn-off to Callington.   There is no mistaking the character of these rocks, which consist of black carbonaceous slate with chert, and massive

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* It may be possible that some of the altered rocks which skirt the granite and form the high ground south of Stamford Spiney, and east of Walkingham and Meavy, may belong to the Culm-measures, having escaped removal by denudation.

greenish sandstones with plant-remains. On the south side of the fault are the grey and purplish argillaceous slates of the older series dipping to the south-west at a high angle, while the grits opposed to them on the other side of the fault undulate off to the north ; but as a whole the position of these Culm-measures is not very much out of the horizontal, while the underlying rocks are highly inclined. This is the most southern spot at which the Carbonaceous rocks have been observed, and it shows conclusively that they once stretched considerably further to the south, prior to their removal by denudation.

It has been necessary to be thus minute in describing the southern limit of the Culm-measures, in order that the relation between them and the underlying series might be clearly brought to view ; and if we trace the line on the map (Pl. XVI.) it will be seen that although there is apparent conformability in some places, yet, when looked at as a whole, it is obvious that the upper group is not always resting on beds of the same age. From this it would appear that the forces which resulted in bringing up the granite of Dartmoor and the Camelford Hills, and which have thrown the beds into their present position, having been posterior in age to the Culm-measures, have acted equally on both formations, and, in producing the major and more manifest foldings and contortions, have somewhat modified and obscured the unconformability which originally existed between them. Following the lower beds as they trend up from the north of Hingston Down by Stoke Climsland to the north-westward, the overlying series crops out, and the lower rocks then occupy the whole of the country between the granite and the Culm-measures of Laneast Down, and show a clear succession from below upwards. Hence the Carbonaceous rocks of Nighton and Trevage cannot be resting on beds of the same age as do those of Laneast Down, unless all the evidences of superposition are to be disregarded. Before proceeding to the consideration of these lower rocks, however, it will be well to notice briefly the relations between themselves of those rocks which make up that portion of the Culm-measures included between the line of outcrop indicated above on the south, Dartmoor on the east, and the range of limestones which extend from Truscott near Launceston, past Lifton, Lew Trenchard, and Bridestow, towards Oakhampton, on the north.

Fully to understand the structure of this triangular area it is necessary to bear in mind that all the igneous rocks contained in it are of the character of volcanic ash and lavas, and were contemporaneous with the rocks among which they are included. There are compact and crystalline rocks among them, it is true ; but they are associated in such a manner with other rocks of similar composition, that have a vescicular or schistose structure, as to leave no room for doubt upon this head ; and not a single instance was noticed of a trap-rock of undoubtedly subsequent age*. In attempting to un-

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* It would be premature to attempt to define the mineral character of these rocks until they have been analyzed. They appear, however, to consist of a felspar which is usually green, less commonly white, and of a dark-green foliated mineral which, as observed by Boase, is something between chlorite

ravel the structure of this intricate country this distinction becomes of importance, as these interbedded volcanic rocks afford great assistance, inasmuch as they serve to separate the slates and grits into horizons, and otherwise act as landmarks to the geologist.

If, now, we endeavour to picture to ourselves a broad sheet of lava, ash, and cinders spread out horizontally round about Brent Tor, reaching from what is now the Tamer to the Tavy, and southward to the parallel of Tavistock, and then imagine this sheet of volcanic rocks, together with those that underlie it, thrown into a narrow anticlinal fold along a line extending from Ramsdown past Dunterton to the Tamer—and a second such narrow line of elevation passing through Upperton towards Bowdon Down—and a third similar, but longer and yet narrower axis extending from the south of Milton Abbots and north of Lamerton towards Petertavy, at the same time depressing the area about Heathfield Down so as to trough higher beds, and raising that of Black Down on the east, we have a rough idea of the arrangement of the beds before us. Thus the volcanic rocks of Lamerton are a more southern portion of those of Milton Abbots and Charlhanger, thrown over a long sharp anticlinal axis,— narrow on the west, where they dip under the slates and grits of Twowell Down, and broader on the east of Lamerton, especially in the vicinity of Kilworthy and Wilminston, where they lie more horizontally.   So with the volcanic beds of Upperton and Wick, which are a part of the same as the Milton Abbots beds rising up again from beneath the slate, chert, and grit of Heathfield Down, to be thrown over to the north at Quether. The ash extending from South Brent Tor to Burn, parallel to the railway, remarkable for its highly vesicular structure, appears to be the continuation of the Milton Abbots ash-bed faulted off at Burnford Farm, and thrown over to the westward of the anticlinal axis of Black Down ; and the ash-bed of Rowdon belongs to the same geological horizon. The section (fig. 1, p. 409), across Heathfield Down, from the Mill Hill Slate-quarry, near Tavistock, to the Thistle Brook at Stowford, will show the general relations of these rocks.

Several faults appear to traverse the country in the vicinity of Brent Tor.   One of these crosses the Lyd river south-west of Coryton, and ranges by Monkstone to the west of the Tor. Another skirts the north-east side of the volcanic rocks of the Tor, extending from near Monkstone to South Brent Tor.   These faults carry the country on the east further to the south, or rather south-east, and reverse the dips along the valley of the Tavy, where the beds rise to an anticlinal axis, which crosses the railway in a N.N.E. and S.S.W. direction, midway between Ford Gate and the Marytavy Railway Station.

and hornblende.   Augite and hornblende are of less frequent occurrence, and then only in the more compact varieties.   Many of these rocks are highly calcareous, the lime being sometimes diffused among the volcanic materials as a constituent of the rock ; in other cases it has been merely infiltrated into the cavities of vesicles at a subsequent period.   Near the granite these rocks have been altered both in their crystalline condition and in the arrangement of their elements ; and of the resultant minerals hypersthene appears to be one. See further De la Beche, Rep. p. 119 *et seq.*

The volcanic rocks on the north of Dunterton and Quether pass under a belt of dark slates and chert, which ranges up from Landūe, south of Launceston, by Greston Bridge to Staddon, and thence to Littonary Down, where, thrown to the south-eastward by the fault already mentioned, it is continued by Bowdon Down to East Longstone ; and this in turn passes under the higher band of volcanic rocks of Bradstone, Chillaton, and West Longstone. It is this chert and its associated grit and slate which constitute the higher beds of Heathfield Down, on the west of the Brent Tor faults.

Still higher beds, consisting of dark-blue and greenish-grey slates, with seams of grit and nodules of ironstone, range up from the Tamer north of Bradstone, by Kelly and Marystow, and along the valley of the Lyd river to the Lydford railway-station, and thence pursue a north-easterly direction by Lydford and Downtown to the granite. These slates are finely exposed in the railway-sections between the Lidford and the Coryton stations. They are evenly laminated, dip northerly, and rest upon the volcanic rocks of Chillaton and West Longstone. The volcanic rock of Medwell appears to be the same as those of Bradstone and Chillaton, cropping out on the north side of a narrow synclinal fold which extends from Kelly to Green Cross, while the chert of Lawhitton, Hardow Down, and Kelland is the underlying rock of Staddon and Littonary Down again brought up to the surface, separated from the chert of Gordon Hill by the northern continuation of the Lyd-river slates, which range by Trenefell to the north of Tremale, where they are worked for roofing-purposes.

On the north of this belt of slaty rocks are the small lenticular deposits of dark-blue or black limestone of Cury Park, Poleat Corner, and Coryton Railway-station ; and beyond these there is a range of chert-beds, which constitutes an important feature in the country, and forms a ridge of barren land which is easily followed. This chert forms the high ground of Gordon Hill, east of Launceston, where it is underlain on the north by black slate and the limestone south of Timber Bridge, and is continued east of the Tamer, by Sydenham and Leigh Down, to the Lew Water. It includes the volcanic ash-beds of Whitley and Leigh Down, and is exposed in quarries by the side of the railway west of Sydenham. A second patch of chert, which, although on nearly the same line of strike, appears to be disconnected from the last, is seen immediately to the north of the limestones of Poleat and Cury (some slates, however, intervening), and is continued on the north side of the road to Watergate, through Burley Down, to a farm marked Buddle Brook on the Ordnance Map. This chert occurs for the most part in rather thin beds ; but they are contorted and crumpled to such an extent that the beds are often folded completely back upon themselves, and in looking at them it is impossible to avoid the conclusion that the more argillaceous slaty rocks cannot have escaped the influence of the forces which have contorted these harder rocks in so remarkable a manner, although it is not equally apparent in them. Slaty rocks lie to the north of the chert-beds similar to those on

Fig. 1.—*Section from the Limestone at Stowford to Mill Hill Quarry, near Tavistock.*

a. Devonian Slates.   b. Cu'm-measures.   c. Volcanic Rocks.   d. Limestones.
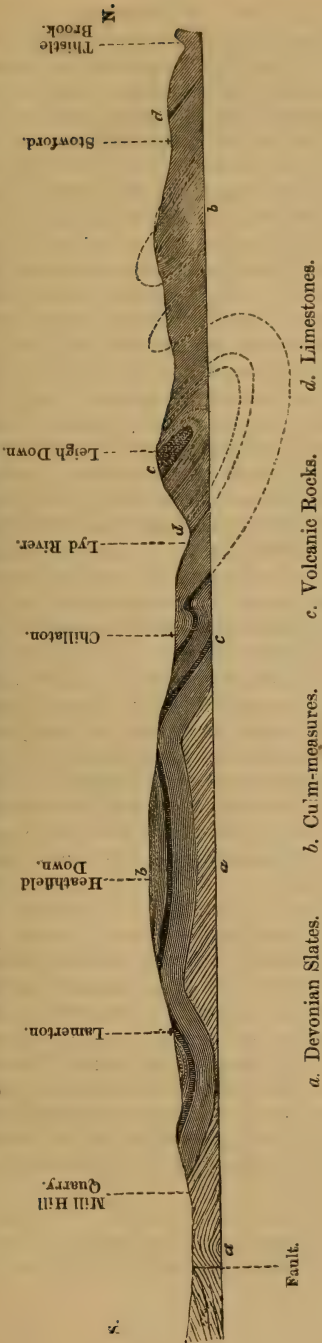
Fig. 2.—*Section from the Chud Brook through Waddon Barton to Higher Dunscombe.*

a. Alluvium.   b. Culm-measures.   c. Culm-measure Slates, with *Posidonomya*, &c.   d. Greenish Grits and Slates.   e. Devonian Slates.
f. Devonian Limestone.   g. Trias.
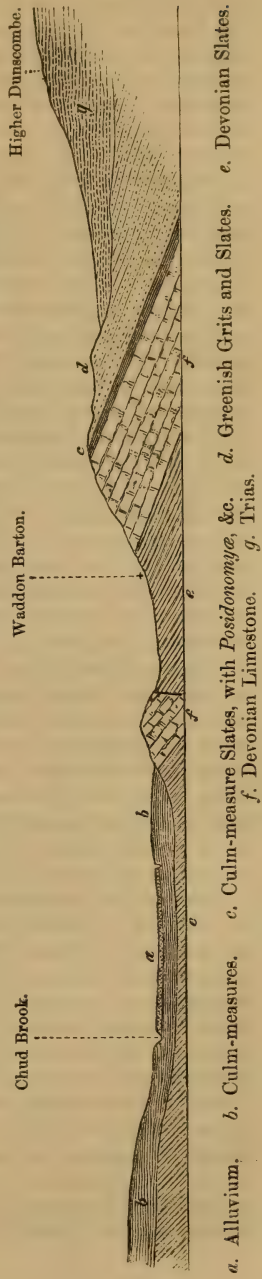
the south, beyond which are the southernmost limestones of Timber Bridge, near Lifton, and of Tinhay, and those of Lew Trenchard, Point Bridge, and Bridestow, which return by Thrastleton, Stowford, Thistle Brook, and the smaller patches north of Tinhay and Timber Bridge, the included area being occupied by the lower rocks of the Lyd river brought up to the surface by the anticlinal axis of Old Street Down.

The chert of Gordon Hill is not continued to the west on the same parallel; but on St. Stephen's Down, on the road from Launceston to Yeolm Bridge, similar chert occurs, and ranges westward towards Egloskerry. This chert occupies the centre of a synclinal trough, the underlying Devonian rocks being brought up to the surface along a narrow axis on the north, which extends from Underwood Farm to Yeolm Bridge, while a lower axis on the south ranges east and west through the town of Launceston. A bed of limestone, together with some volcanic ash, underlies this chert at Calvanna Park, near Lower Truscott, which bears the same relation to the siliceous rock above as the limestones of Coryton and Timber Bridge do to the chert of Gordon Hill and Sydenham. Between the anticlinal axis of Yeolm Bridge and the lower rocks of South Petherwin we appear to have, therefore, the whole of the Culm-measure series from the limestones downwards; but we miss from the rocks south of Launceston much of the volcanic ash, and most of the grit and chert which characterize the Carbonaceous system along the banks of the Tamer. Brent Tor, or its vicinity, as already suggested by Sir Henry De la Beche[*], was probably the centre of volcanic action, and this may sufficiently explain the somewhat local distribution of the igneous products. The rocks forming the Tor are composed in great part of cinders, some of large size, mingled with ash, cemented into a kind of conglomerate, the vesicles being filled sometimes with carbonate of lime, at others with chalcedony. Neither in their mineral nor in their physical character do these volcanic rocks differ more than those of modern eruptions; the lavas are sometimes vesicular, at others crystalline and compact, the ashes more or less schistose and mixed with cinders, and the whole commingled in a manner that shows their common origin[†].

It is difficult, therefore, where igneous and arenaceous rocks are intercalated so irregularly among the slates, to form even an approximate estimate of their thickness. If we take the distance from the lower rocks brought up by the anticlinal axis at Underwood Farm to the middle of the chert troughed in the synclinal fold on the south, at Upper Truscott, the distance is barely three-fourths of a mile, which, at a maximum average dip of 35°, would give little more than 2000 feet; and if to this we add half as much again for the increase of arenaceous materials and intercalated volcanic rocks on the banks of the Tamer, we shall probably arrive at as near an approximation as we can make.

[*] Rep. p. 122.
[†] The vesicular structure of some of these rocks would lead us to infer that they were accumulated, in part at any rate, on dry land.

The relations between the Culm-measures and the lower rocks north of South Petherwin are not altogether so clear as could be wished. The Carbonaceous rocks dip to the north; but the underlying slates are a good deal rolled, and their dip is not easily made out. Following, however, the line of outcrop from the Landlake quarry by St. Lavers to the south, the Culm-measures may be said to arch over the older rocks brought up between South Petherwin and Trekenna (see section fig. 3, p. 417), with minor east and west undulations; and in the deep synclinal trough of the Inny there are some of the higher beds (the slates south of Beal's Mill), which occupy the axis of the trough, corresponding probably in age with those of the Lyd river. The volcanic rocks, however, are absent, and the chert is for the most part replaced by grits.

Near Bridestow, the chert-beds of Watergate thin out, and the dark slates to the north and south of them are brought together, and are continued by Sourton and Oakhampton Park round the north side of the Dartmoor granite, which has pushed the Culm-measure beds to the northward, and brought them into vertical or highly inclined positions. It is not necessary, however, for the objects of this communication, to follow these beds further in this direction. I proceed, therefore, to notice briefly the relations existing between the lower Culm-measures and the underlying rocks as they occur on the east of Dartmoor.

Along the margin of the granite from East Down, near Lustleigh, to Skeriton, south of Holne, the Culm-measures consist of slates and grits with chert-beds very similar to those which occur north of Tavistock. The chert is perhaps not so abundant; but a siliceous rock, somewhat less flinty, is plentiful between Bickington and East Down; and volcanic admixtures occur near Ilsington, and become frequent further north between Chudleigh and Dunsford. Near the granite the rocks have become altered by it; and the resulting metamorphic rocks resemble those on the west and north-west of Dartmoor, showing their close similarity in mineral character. Near Ilsington they contain plant-remains, and Goniatites have likewise been found in them.

We may safely assume, I think, these rocks to be the equivalents in part of that portion of the Culm-measures which occurs south of the Lyd river, and to occupy a position at or near the base of the series. They dip, as a whole, away from the granite, to the east and south-east, but are much undulated and contorted, and hence counter dips are frequent. The line between the Carbonaceous rocks and the Devonian slates and limestones emerges from beneath the Bovey beds at Black Pool, and extends by the New Inn southward to Bickington. So far the line appears to be a line of fault, Culm-measure grits and slate very highly inclined to the eastward being brought against the Bickington limestone, dipping south-east at an angle of about 25°. This fault appears to run into another short fault, which extends north-west and south-east, and cuts off the Bickington limestone from its continuation with the Ashburton mass at Lemonford. From the factory north of Lemonford the line, as laid down on the

Geological Survey-map, then passes by Higher Way to the Druid's fault. The want of exposures, however, makes it very difficult to determine whether or not the slates at Alston and Way, which dip towards the Ashburton limestone, may not be Culm-measures brought against it by a fault parallel with the turnpike road. The nearly east and west fault which passes Rew Mill, and which is in part metalliferous, being now worked for copper at the Druids' mine, throws up the underlying Devonian rocks included between it and a nearly parallel fault which ranges from about a quarter of a mile south of Holne Bridge, past Christophers and Pridhamsleigh, to the south of Bulland. These lower rocks thus faulted up dip under the volcanic rocks and limestone of Ashburton; but about three-quarters of a mile from the town, on the road to Buckland-in-the-Moor, they appear to make a turn over, and become, first vertical and then reversed, at an angle of 65° to the south-east; and at the Druids' Farm they contain *Spirifera disjuncta*, *Chonetes sordida*, *Petraia bina*, and *Cyathocrinus pinnatus*? Following these fossiliferous beds along their line of strike to the south-west, we find them again in the descent to Holne Bridge, with abundance of *Spirifera disjuncta*. It would appear, therefore, that these beds are well in the Devonian rocks, and probably not very much below the base of the Ashburton limestone. If we follow them across the Dart, however, we find, just before entering Hembury Wood, that they abut against a mass of thick-bedded grits, with black slates which clearly belong to the Culm-measures. These rocks are highly flexed, and are confined to the east side of the river, where they form a steep ascent of some elevation. On the opposite side of the river the ground is low and consists of slate. Although the two series are not seen in actual contact, it is yet clear that they dip in opposite directions, and that they are brought into apposition by a fault. In all probability this fault runs into the Brook Mill lode south of Hembury Castle; and, in fact, it would appear that the north and south fault we are alluding to is itself metalliferous, as there are the remains of an old copper-mine on the banks of the river. Southward of the Brook Mill lode, it is impossible to draw the line with any approximation to accuracy, not simply from the want of exposures, but also from the country being covered with fragments brought down from the higher ground on the west; but to the eastward of a line thence by Skeriton we are clearly on the Devonian rocks*.

South of Newton Bushell there is a small outlying patch of these Culm-measure grits and slates, which occupies a depression in the Devonian rocks immediately to the east of the limestone of Og-

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* The grits west of Bickington are succeeded by argillaceous slates, which undulate as far as Ramshorn Down, where they pass under the chert-beds of Combe. Now, in some of these beds, Prof. Phillips mentions the occurrence of fossils (Pal. Fos. p. 203); but I was not aware of this circumstance until too late, and therefore did not specially examine the locality with a view of ascertaining the position of these fossiliferous beds; if, however, they belong to the underlying Devonian series, they must be brought up to the surface either by a sharp anticlinal axis, or by a fault parallel to that of Bickington.

well. These beds rest unconformably on the older rocks, as noticed by Mr. Godwin-Austen[*], who found at their base a conglomerate of rounded pebbles of quartz with angular fragments of the subjacent limestones [†]. Through these Carbonaceous slates and grits the limestone of Connator forms a protrusion, and on the east they are brought against the argillaceous slates of the Totnes turnpike-road (which underlie the limestones) by a north and south fault, with downthrow on the side towards Ogwell [‡].

Crossing over to the other side of the Bovey deposits, we find precisely similar Carbonaceous slates and grits, occupying the country north of the Kingsteignton limestone, overlain by Triassic conglomerate on the east, and by the Greensand and Bovey deposits on the west. Through these slates and grits, the limestone of Kingsteignton, Orchard Well, Ugbrook Park, &c. forms protrusions, the Carbonaceous rocks occupying the hollows between them. The slates south of the Kingsteignton limestone, much of which is purple or claret-coloured, belong to the Devonian system. They appear to rise from under the limestone and associated igneous rocks, which latter have altered them at the line of contact; and they occupy both shores of the estuary between Bishopsteignton and the Bovey beds of Newton.

North of Ugbrook Park there is a long curved strip of the older limestone, containing Devonian fossils, which appears to be faulted up, as the strike of this limestone is oblique to that of the Culm-measures, which occupy lower ground. At Waddon Barton this limestone is overlain by hard slates full of *Goniatites* and *Posidonomyæ*, above which are the typical Carbonaceous sandstones quarried at Ugbrook Park. Purplish and grey slates, with calcareous concretions, underlie this limestone, and are exposed in the hamlet of Waddon, where they are clearly seen to dip under the limestone. Beyond these, nearly midway between the cottages and the Chud Brook, there is an off-standing knoll of shattered limestone, which appears to be on a line of fault. The low ground through which the Chud Brook flows is partly occupied by alluvium; but we learn from Mr. Godwin-Austen that a well-sinking, which was formerly made here, passed through 15 feet of perfectly horizontal carbonaceous slate and sandstone resting on highly inclined slates, similar to those seen beneath the limestone at Waddon, and dipping in the same direction[§]. The section (fig. 2, p. 409) taken across the beds at Waddon Barton in a south-easterly direction, will serve to show the general structure of the country.

Northward of Chudleigh the Culm-measures undulate towards

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[*] Geology of the S.E. of Devonshire, Trans. Geol. Soc. vol. vi. 2nd ser. p. 457.
[†] *L. c. suprà*, p. 458.
[‡] Sir Henry De la Beche appears to have considered this fault an upcast on the east (*vide* Rep. p. 111). On the contrary, it appeared to me that this small patch of Carbonaceous rocks has been preserved where it is by having been brought down below the general level of the country, and so escaped denudation. The bedding of the Connator limestone appears to be vertical; but it may have been brought into that position before the Culm-measures were deposited.
[§] *L. c.* p. 460.

Ashton and Dunsford, the direction of the bedding being south-west and north-east. The beds are broken through on the west by the granite of Dartmoor, and on the east by the limestone of Whiteway and Uppercot. Grits and volcanic rocks are abundant, the latter corresponding in general position to the similar rocks in the vicinity of Brent Tor; and near the granite they become crystalline and more or less altered, and lose all trace of their mixed igneous and mechanical origin.

It is not the intention in this communication to enter into a detailed account of the Carbonaceous rocks generally. For a further description of them, reference must be made to the original memoir by Sir Roderick Murchison and Professor Sedgwick, in the 5th vol. of the Transactions of this Society (2nd ser. Part 3, pp. 669 *et seq.*). It is to these authors that we are indebted for having first pointed out the true position of these rocks in the geological scale, when, by means of the included plant- and other fossil remains, they identified them with the Coal-measures of South Wales.

III. Devonian Rocks.

1. *Beds below the Plymouth and Torbay Limestones.*—The lowest rocks in the district to which this communication more particularly refers have been upraised around Hingston Down, and, between the granite of Dartmoor and the Tamer, in the vicinity of Buckland Monachorum, Beer Alston, and Roborough Down, near Bickleigh. On the confines of the moor, around Harrowbridge, Walkingham, and Meavy, the beds dip away from the granite at low angles; but to the south of Bickleigh Railway-tunnel, the granite has broken through the bedding, which ranges up to it, at right angles to its margin, with a southerly dip. These beds consist chiefly of pale greenish and grey argillaceous slates, sometimes soft and silvery, and often veined with quartz; but grit seams are not common. North of Harrowbridge and Buckland-Monachorum the prevailing dip is to the south-west; but the country is much disturbed by faults and metalliferous lodes, and southerly and westerly dips are not wanting.

At Morwellham Quay, on the Tamer, the beds are greatly contorted; and contortion is also seen in the valley of the Tavy, near Romans Lee, and on the east of Lumber Bridge; but easterly dips occur on Morwell Down and about Gulworthy, and north-easterly dips at Mill Hill quarry, thrown off from the granite of Hingston Down. From these twin granitic protrusions the beds dip away in all directions; those on the north, however, become horizontal at Latchley Ford, and then rise gently to the north, but are disturbed at Horse Bridge and Hartwell by a fault which has brought them against the Culm-measures. On the south of the down the beds range from the Tamer by Tiddeford to the north of Callington, with a southerly dip at an angle of from 25° to 30°, and pass under higher beds south of the town. On the south of Beer Ferrers and Bickleigh these green and grey slates pass under higher beds, which between Tamerton Foliot and St. Budeaux are partly blue and purple.

The country to the west of the Tamer is thrown down by the partially metalliferous faults of Calstock and Colete. A fault which ranges east and west by New Bridge, on the Notter, with upcast on the south, repeats some of the rocks between it and Callington ; but the dip is to the south, and higher beds come in about Pillaton Down and St. Mellion, south of which a second nearly east and west fault throws down the country, and with it a patch of Culm-measures, at Pentre Cross. In a similar manner faults have brought down the area around Linkinghorn and South Hill ; but lower beds occur on the west of the Notter, between it and the granite at Caradon.

The elvans, which are associated with these lower slates as we approach either of the great granitic masses of Dartmoor or the Camelford Hills, although sometimes parallel to the strike, have no relation to the plane of the bedding. Some of them may have been contemporaneous with the outburst of the granite, filling in fissures made by the same disturbing cause, as in the vicinity of St. Neot's and Blisland ; but others, as near Redruth and Penryn, are seen to traverse the granite as well as the adjacent rocks, and must therefore be somewhat more recent. It is otherwise, however, with the volcanic rocks which are associated with the slates, and which occur more or less abundantly on certain horizons. They lie in the plane of the bedding, and were contemporaneous with the rocks among which they occur. Their structure is often schistose or vesicular ; and many of them are rich in lime, which in the vesicular varieties has been infiltrated into the cavities. With this ash, whether schistose or vesicular, there is often intermingled more or less fused rock, in such a manner that it is very difficult, as observed by Sir Henry De la Beche, " to see where the one variety of igneous product ends, and the other commences " *. It is seldom that even the compact portions have produced any very obvious effects upon the subjacent slates.

As the rocks between Hingstown Down and the southern edge of the Culm-measures range by North Hill towards Alternan, they dip away from the granite at angles which do not appear to exceed 10°, and are often less ; and in doing so they pass under the Culm-measures which extend by Coades Green to within a mile of the Penpont Waters, capping the higher grounds as they rise to the north-west. These lower rocks form a belt of country consisting of slates and ash-beds, which strike north-west and south-east, the angle of dip varying from 5° to 10° or 15°. At Holloway Cross and Trewen, westward of the line of fault, near Kneller's House, these ash-beds pass under overlying slates, which dip to the northeast with the same low undulating dip (under 15°), and include the limestone and fossiliferous slates of Trenalt and Tall Petherwin ; and as the ground rises some 300 feet or so, we come rapidly upon higher beds, which are finally overlain by the Culm-measures. At Treguddick Mill some of the slates which underlie the ash are brought up by a short, sharp anticlinal axis, which throws the volca-

* Mem. Geol. Survey, vol. i. p. 82.

nic rocks over to the northward, after which they both dip under the higher beds of Tall Petherwin and Treguddick Farm.

To the eastward of the fault before mentioned, which runs down to Treveny, the country opens out in the direction of the Tamer; and north of Trecarrel Bridge lower rocks rise from beneath the Lewannick belt of volcanic ash, and form a ridge, which, commencing at East Penrest, where the beds emerge from beneath the Culm-measures of Cuddicombe, passes by Trebollets, Pollinny, and Trecugar to South Petherwin, and is then continued by Oldwell to the north of Trevoza, where these lower beds again pass beneath the Culm-measures. These lower rocks consist of evenly laminated pale-green slates, and are apparently unfossiliferous. As a consequence of the upheaval of the beds eastward of the Treveny fault, the continuation of the higher fossiliferous slates of Tall Petherwin and Trewen, with their included limestones, is carried to the northward, by Little Petherwin and the south of Doe's Houses, to the Landlake limestonequarry, where they pass beneath the Culm-measures of Haldon Down. On the other hand, we have within this semicircular ridge, occupying the lower ground round about Trewarlet and Larrick, and on the eastward of Lower Linnick, some of the same fossiliferous slates with calcareous seams (see fig. 3).

These upper beds are less uniform in their petrological character than the pale-green slates below them. They consist chiefly of olive and brownish slates, more or less rust-stained on the surface, and often cleaved and splintery. Interstratified with them are thin ochreous seams, which occasionally contain fossils; and some of the olive-brown slates contain numerous minute points of ochreous matter, the remains of some decomposed crystals, which give them a speckled appearance. This is so frequent in the upper beds of this vicinity as to be almost characteristic. The still higher slate rocks, however, or those immediately beneath the Culm-measures, north of Holloway Cross and Trewen, are softer and thicker, and much of them is of a very pale colour and an even texture.

The limestone at the Landlake quarry dips N.N.E., at an angle of 20°; and it is from this spot that by far the larger part of the South Petherwin fossils have been obtained. The other two limestone patches appear to be less highly inclined; but there is some difficulty in making out the dip satisfactorily, as the rocks are here much rolled, and, moreover, they are affected by cleavage which in some places is inclined in an opposite direction to the bedding, as, for instance, in descending the hill from Little Petherwin. There appears to be no reason to doubt, however, that these three small calcareous patches are on the same line of strike, curved round to the northward of, and rising up to, the upraised lower rocks on the south. Some of the associated slates, in fact, may be seen capping the highest ground in the lane due east of South Petherwin, where the included ferruginous seams contain *Orthoceras ibex*, Phill., a *Clymenia* much flattened, and some other shells; *Spirifera disjuncta* and *Spirifera Urii* occur also abundantly in some slates halfway up the hill south of the Landlake quarry. In the quarry south of Doe's

Fig. 3.—Section from Yeolm Bridge to Pengelly, near Linkingham.

Yeolm Bridge.
St. Stephen's Down.
Launceston.
South Petherwin.
Pollinny.
Inny River.
Higher Pengelly. Trelabe.

e. Elvan.
d. South Petherwin Limestone.
c. Volcanic Rocks.
b. Culm-measures.
a. Devonian Slates.
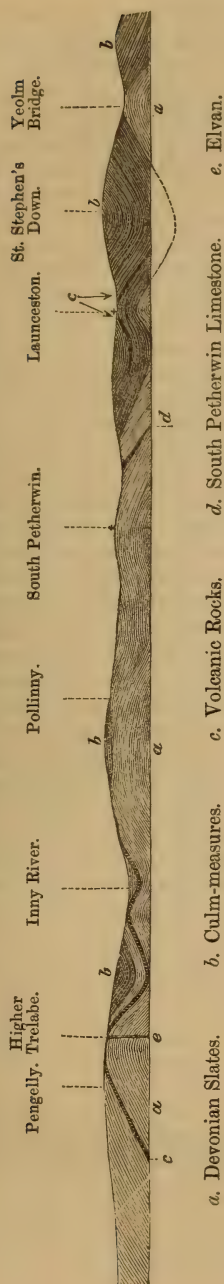
Houses, fossils are specifically far less numerous than they are at Landlake, the only additions to the already known species from this locality being *Tentaculites annulatus*, Schloth., and a small undescribed species of *Serpula*; but the limestone at Little Petherwin, although in the same mineral condition, contains few or no fossils. Underlying these calcareous beds are two small patches of volcanic rock, the one a little north of South Petherwin, the other at Bolathan, a mile to the west of the former; and it is perhaps worth noting that these igneous rocks hold pretty much the same relative position to the Petherwin limestones that the larger band of Lewannick does to the limestone of Trewen, and may possibly be offstanding patches on the same horizon. Fossiliferous slates containing *Spirifera disjuncta*, *Cyathocrinus ellipticus*, and an *Orthis* occur in the lane leading from Trekellearn Bridge to Pollinny, about halfway up the hill; and the similar olive and speckled slates with ferruginous seams, which occupy the depressed country round about Trewarlet, and beneath which the pale-green slates of Brocka and Trevoza are seen to dip, are again fossiliferous at Larrick, Trewarlet, and the south of Laudue; and on the banks of the Inny below Round Bury, troughed among the beds which overlie the volcanic rocks on either side of the river at Trecarrel Bridge, a small patch of highly calcareous ash occurs, which appears to be sufficiently on the same horizon as the limestones and calcareous seams of south Petherwin and Trewarlet, to be regarded as belonging to the same group.

It would appear, therefore, that the place of the limestones and calcareous seams of South Petherwin,

Trewen, &c. is at a short distance only above the uppermost belt of volcanic rock, or that which extends from Trecarrel Bridge, by Lewannick, to Laneast. The overlying slates attain their greatest thickness in this vicinity, north of Holloway Cross and Trenalt.

Three miles to the north of South Petherwin, these lower rocks are again brought up to the surface by a narrow anticlinal axis at Yeolm Bridge, which extends westward by Underwood Farm. These slates are sparingly fossiliferous; but the few species that occur at this locality are all South Petherwin forms, with the exception of *Sanguinolaria elliptica* and *Bellerophon hiulcus*, of which latter, I believe, only a single very imperfect specimen has been met with, and this may have come from the overlying Culm-measures[*].

The attempt to ascertain the relative position of the several beds of ash is attended with considerable difficulty, owing to the paucity of good exposures and the uncertainty regarding the true dip of the beds. The belt of volcanic ash which extends from Tregue Cross by Penhale to the south of Davidstow, appears to be the same as that which ranges up from North Hill to the west of Alternan, broken off and carried further to the northward by the granite of Brey Down; but the strip of Culm-measures which runs up from Coades Green to as far as Trebant, obscures in great part the older rocks which dip away from this igneous belt to the north-east; and the slates which further on rise up from beneath these Culm-measures, and range by Alternan and Tregue Cross, are altered by the granite. Crossing the country, however, from Trevillans gate by St. Clether, we have apparently a clear upward succession of strata, all the way to the Carbonaceous rocks of Coose Moor. The volcanic belt of St. Clether consists of an upper and a lower band separated by beds of more schistose ash (along which the river runs), and has a north-easterly dip, at an angle of about 20°. From this belt, a little further to the east, at Laneast, we have again apparently an upward series to the Culm-measures of Laneast Down, all the dips obtainable being north-easterly. The intermediate belt of igneous rock, or that south of Laneast, is highly calcareous, and has some beds of limestone at the top—a character which it possesses in common with the volcanic rocks of Titch Beacon, which strike up to an impure limestone at Grills, near Lesnewth, and appear to be on the same horizon.

Fig. 4.—*Section from Minwonnet by Pollaphant to the Granite near Newton.*

a. Devonian Slates.   b. Culm-measures.   c. Granite.   d. Volcanic Rocks.
e. Limestone.
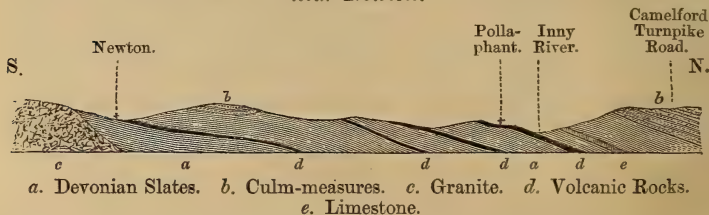
[*] Phill. Pal. Foss. p. 139, pl. 58. f. 203.

The two masses of volcanic rock on either side of the Inny at Trecarrel Bridge appear to be portions of the same band, troughing some of the higher beds between them, as already noticed. A tolerably good section is seen in the lane leading from the bridge to Tregvis, the volcanic rocks rising as an arch, which throws off a thin covering of the higher slates ; on the south these undulate for about a hundred yards, when the volcanic rock again rises, overlain by the slates. A little further on, these rocks are overlapped by the Culm-measures.

The belt of slates in which the volcanic rocks we have been considering are included is readily followed westward from St. Clether, by Davidstow and Lesnewth, to the coast at Trevalga, where they curve south-west to Tintagell, and are there associated with slates that contain *Petraia Celtica*, *Phacops latifrons*, *Strophalosia productoides*, *Spirifera disjuncta*, and its varieties *gigantea* and *inornata*, *Rhynchonella pleurodon*, *Pterinea subradiata*, and *Spirifera speciosa*, all of which, with the exception of the last two, are also met with at South Petherwin. The greenish-grey slaty rocks which support the volcanic belt of Tregue Cross and Penhale dip under it, and strike, by Trevillan's and St. Kitt's, round the north-westward of Cadon Barrow, lower rocks containing some thin grits being brought up south-eastward of the barrow, and about Camelford. To the westward of these lower rocks, and overlying them, there is a belt of similar greyish slates striking up from below the volcanic beds of Tregreenwell, east of St. Teath to Delabole, where the rock has long been worked for roofing-slates, and thence to the Trewarnet slate-quarries, where it curves round to the coast at Tregatta. The exact mode in which this range of slates is brought into contact with the higher rocks of Tintagell is somewhat obscure ; but the abrupt change in the direction of the strike suggests the probability of a fault crossing the country somewhere betwen Tregatta and Tintagell. The dip of the Delabole and Tregatta belt of roofing-slates is to the west, south-west, and south, as they curve round to the coast ; and if they are, as they appear to be, the same as those which support the volcanic rocks of Tregue Cross and Penhale, the higher beds of Delamear Down (under which these slates dip) must be the same as those of Davidston and St. Clether, but without the interstratified bands of igneous rock. These latter, however, again come in south of St. Teath, where the beds begin to widen out to form a broad shallow trough with minor axes ; and as this trough trends round to the westward, it deepens, and includes higher beds, some of which are calcareous and correspond in geological position with the fossiliferous beds of South Petherwin. The slates which include these ash- and lava-beds, and support the higher rocks troughed in the synclinal axis, form therefore two belts :—a northern, which trends east and west from the south of St. Teath, at Treburget, to Pentire Point; and a southern, which is continued by St. Tudy and St. Mabyn, and then curves round to the Camel river at Egloshayle, beyond which it is continued without the volcanic bands, by the south of St. Breock and St. Ervan, to the coast at Bedruthen. Some of these volcanic bands

are no doubt the same beds repeated by the subordinate anticlinal and synclinal folds ; and faults may have destroyed the continuity of a bed, and thrown it out of the line of strike, as is the case in the vicinity of Padstow.   The limestones and fossiliferous bands range on either side of the axis of the trough, which trends from Constantine Bay, by Padstow and St. Michaels, to Lower Amble, round to the south-east of St. Kew ; and some of these higher beds consist of purplish argillaceous slate very similar to some of that associated with the volcanic rocks of Saltash and St. Germans, to be noticed hereafter.

The fossils of the Padstow district occur chiefly at Permizen Bay, Dinas Cove, and Penquean, and consist of *Petraia Celtica, Phacops latifrons, P. laciniatus, Athyris concentrica, Atrypa desquamata,* and *Orthoceras Ludense,* Phill. (which are also South-Petherwin forms), *Spirifera speciosa, Pentamerus brevirostris, Streptorhynchus umbraculum, Stringocephalus giganteus, Cyathocrinus megastylus* (which are Middle Devonian), and *Spirifera hysterica,* which is a Looe and also a Lynton species, but is said to occur likewise in the limestone of Woolborough near Newton Bushell.   From Bedruthen Steps, Mr. Pengelly has obtained specimens of *Pteraspis Cornubicus,* M'Coy ; and this is the lowest horizon on which it has hitherto been observed. We have therefore six species occurring in the Padstow area in common with South Petherwin, and six in common with the Looe-river district, with two that belong to intermediate stations, viz. *Spirifera speciosa,* which occurs also at Tintagell, and *Phacops latifrons* at Liskeard.   See Table III., p. 450.

These rocks rise, on the south of the trough, to the anticlinal axis of St. Breock's Down ; and in all probability the slates which contain the calcareous and fossiliferous rocks of St. Columb Porth and New Quay, are the same beds repeated on the south side of the axis[*]. This axis extends from the coast north of Trenance Point, near Morgan Porth, to the Camel above Polbroke, and brings up lower rocks, which consist chiefly of thick pale-coloured slates with bands of hard grey grits, the whole much traversed with veins of quartz, fragments from which, mingled with those from the grits, are strewed abundantly over the surface of the down.   Eastward of the Camel, the country to the south of the axis, about Bodmin and Lanivit, is thrown up by the granite of St. Austell, and the dip becomes northerly, at for the most part low angles.   This upcast is aided by a line of fault which extends from the east of Bodmin, by the Black Pool Barrow, to the west of Lostwithiel. The crest of the St. Breock's-Down axis, which is formed by the arenaceous beds, thus becomes relatively depressed ; and the country round about Bodmin, west of the fault, and between it and the Camel, consists chiefly of the thick slaty rocks which form the flanks of the axis, and some unimportant bands of grit, undulating off to the northward.   At the quarries at Castle Canyke, and about Bodmin Down, the angle of dip is about 20° ; south of Bodmin Down bands of grit rise to the south and crop out.

* See, further, De la Beche, Report, p. 88.

To the east of the fault which passes Lostwithiel, and which is probably continuous with the Tywardreath copper-lode, the country is upraised, and the rocks are similar to those of St. Breock's Down, much traversed with quartz veins, blocks and fragments of which lie about in abundance.   The gritty and arenaceous beds form a narrow belt of country, which extends from the north of Black Pool by the Grey Mare and Rye Down, and between Boconnock and Broadoak, to Bucka-Barrows and Bury Down; and the grit beds south of St. Keyne appear to be the continuation eastward of the same belt of rocks.   Opposite the Parsonage at St. Keyne these grits lie horizontally, and there can be no doubt about their passing under the argillaceous and calcareous rocks on the south; but it is not so clear whether they rise from under the slaty rocks on the north at St. Keyne, or whether they are faulted against them.   These grits, with the thick slates which overlie them, together with those which form the high ground between the forks of the Towey River at St. Winnow, and the south-east of Lostwithiel, constitute a somewhat triangular area, having the Lostwithiel fault at its base, which separates and dovetails in between the higher rocks of the Liskeard synclinal trough as it crosses the tributaries of the Fowey, south of Warleggon, and St. Neots on the north, and the rocks of similar age as they strike from the Looe river below Tredinick by Lanreath and St. Veep to Trewardreath on the south.   In this view, I am compelled to differ from the opinion of the late Sir Henry De la Beche, who held that the thick slates and grit beds of Boconnock and Rye Down are higher beds overlying the red slates of Lansalloes and Gregon[*].   The reasons against this will become more apparent when we have followed up the higher rocks from the eastward.

To return to the beds which skirt the Camelford granite on the north-west.   The volcanic rocks of Alternan and North Hill terminate near Kelbrook, being broken through by an elvan; the similar rocks of Bray's Shop, and Pengelly, although the continuity has not been actually ascertained, are probably portions of the same band disconnected by some local disturbances.   The small patch at Treven connects this last with the larger patches of South Hill, Hay, and Callington, and these, again, with another small faulted patch at New Bridge, which last is not very far removed from the line of strike of the volcanic rock of St. Cleer.   These patches do not form portions of a continuous bed; but it is probable that they all belong to the same horizon, judging from the general relations of the rocks of the district—the bed of volcanic rock at St. Cleer on the south bearing very much the same relation to the granite that that of Alternan does on the north, lower rocks being brought up in the interval on the east of the granite at Caradon, Notter Tor, and Bondwall's Mill.   On the east of these lower rocks, the country around Linkinghorne and South Hill, which is on the line of upheaval between the Brown-Willy granite and Hingston Down, is thrown down by the faults at Hay and the Redmoor Mine, and with it a patch of the Culm–measures, in the same manner that

* Rep. pp. 80–81.

the faults of Cotele and Pentre Cross have thrown down the country about St. Mellion.   To the south of St. Ives, however, we come into a belt of country the structure of which is very difficult to unravel, owing to the obscurity of the bedding, the planes of cleavage being so much more strongly marked than the lamination.   Thus at Ten-creek, near Liskeard, and at Hepple Mill, near Quethiock, vertical bedding, in which the stratification is shown by seams of ochreous material, is seen cleaved by planes which dip to the south at an angle of 12°; and at Pope's Mill horizontal beds are cleaved at an angle of 35°, dipping in the same direction; but in the great ma-jority of the exposures it is impossible to ascertain whether the laminæ are those of deposition or of cleavage*.   It would appear, however, that the argillaceous rocks, with their included beds of volcanic ash &c., are here thrown into a series of narrow east and west plications, which succeed each other in an oblique line extend-ing from the neighbourhood of St. Neots to Saltash on the Tamer; but the details are involved in intricacy, as one anticlinal axis dove-tails in between others in a manner that renders it difficult to follow the beds along their strike for any distance.   A synclinal axis, how-ever, crosses the Temple branch of the Fowey below Panter's Bridge, and runs eastward to Mount Coldwind, north of the Doubleboys railway-station, beyond which it ceases to be recognized.   The rocks on the north of Quethiock and Liskeard dip to the south, under beds which are fossiliferous at the railway-station and at the slate-quarry south of Pope's Mill, where they include a bed of argillaceous lime-stone three feet in thickness, first noticed by the late Mr. Giles †. These beds rise again to an anticlinal axis at Menheniot, which runs eastward between the ash-beds at Combe; and this is succeeded by a synclinal trough at Tilland slate-quarry, in which the beds are highly inclined (60° to 80°), and the slates sometimes blue or purplish.   A sharp anticlinal axis follows, which extends from Menheniot railway-station, by Molenick and Notter Mill, to Botes Fleming, beyond which there is a synclinal trough ranging from the north of St. Luke's by Landrake, and across the Tamer to the north of St. Budeaux, containing highly inclined grey, blue, and purple slates, which appear to form one or more subordinate anticlinal folds.   One of these minor folds occurs at Stoketon, and is on the same line of strike as the axis south of Tamerton Foliot, noticed by Prof. Phillips ‡, and another at Trematon.   The slates and volcanic rocks of Saltash and St. Stephens rise on the south of the latter trough, but they appear to constitute rather a series of plications than a single axis.   It would appear, therefore, either that the lamination is deceptive and does not represent the true bedding, or that the plications must be very numerous, even more so in fact than the above description would imply; otherwise the prevalence of ver-tical and highly inclined stratification over a distance of three or

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* The age of the cleavage is clearly subsequent to the period when the beds were brought into their present position, and therefore to the upthrust of the granite. See also De la Beche, Rep. p. 279.
  † Thirty-sixth Ann. Rep. of the Geol. Soc. of Cornwall.   ‡ Pal. Fos. p. 199.

four miles would imply a great accession of deposits unrepresented elsewhere. On the west these slate- and ash-beds appear to rise up over lower rocks; but on the east their relation to the argillaceous slates about Pillaton is not quite so clear, as the nearly W.S.W. fault from Pentre Cross may be prolonged across the Notter at Pillaton Mill, and, if so, would not be without its influence on the rocks of the Tiddi valley.

Assuming that the volcanic rocks of St. Cleer, New Bridge (on the Notter), Callington, Hay, South Hill, and Bray's Shop belong, as I believe, to the same geological horizon as the long belt which, bordering the granite on the north, runs up by North Hill to the south of Alternan, the beds which dip into the synclinal area of Liskeard, and undulate thence to Saltash and St. Stephens, represent in less force the higher group of Davidstow and Lewannick. Folded in among this upper group are some slate-beds locally fossiliferous, as at the Tregril slate-quarry, at Great Tressell north of St. Keyne, Doubleboys, Stoney Bridge, near Liskeard, and in the cuttings of the railway south of the town, and likewise at Saltash and St. Stephens. Among these fossils we find noticed *Pleurodictyum problematicum, Atrypa desquamata, Bellerophon bisulcatus, Fenestella antiqua,* an *Orthoceras,* two species of *Spirifera,* some undetermined *Cyathophyllidæ, Phacops latifrons,* and *P. punctatus.* The last species was found at Great Tressell by Mr. Pengelly, and is a characteristic Middle-Devonian fossil [*].

South of St. Stephens the slates and ash-beds dip to the south. They include some calcareous bands, and pass under a thick series of argillaceous rocks of grey, blue, and purple colours, interstratified with ash-beds, which lead up to the base of the Plymouth limestone. These beds are laminated at a high angle, and apparently the lamination is in the plane of the bedding. East of the Hamoaze the beds seem to form a short synclinal trough, the slates, which are vertical along a line extending from Tor Point to Anthony, dipping northerly at high angles along the shore of Sango Lake. They are, however, again thrown over to the south at Wolsden House, and become undulated and contorted at St. John's, but again dip southerly at Mendinnick, and this dip is preserved all the way to the Rame Head, the slates south of Higher Tregantle being more or less hard and arenaceous, with uneven surfaces, and often interstratified with grit bands. At Wolsden House these contorted beds contain some calcareous seams, and a bed of volcanic ash occurs to the south of the park; a few grit bands may be seen between the village and Mendinnick, but the contortions which may be here observed die out before reaching the coast. The slates of Tor Point, which are there chiefly grey or blue, range past Anthony to Grafthole, where they become reddened and include thin bands of grit. If we recross the beds from the coast at Port Winkle to the limestone of St. Germans, which is on the same line of strike as the calcareous bands south of St. Stephens, we find that the variegated

slates with thin grits, of Grafthole and Port Winkle, are succeeded by the grey slates of Polscove, and these again by the grits of Sheviock Wood, which strike E.N.E. towards Creep; but they are poorly represented, if at all, on the coast, and their place appears to be occupied by the hard reddish arenaceous slates of St. Germans Beacon. A considerable belt of slate occupies the country to the north of these grits, from Sconner to Polbathick and thence to St. Germans, and runs out to seaward between Downderry and the Flag-staff west of the mouth of the Seaton river, the dip being S. 20° E. at Polbathick, and becoming south-easterly on the coast.   Beneath these slates are grit beds, which, striking down from Caracawn Cross to the towns of Looe, overlie or include a band of limestone north of the east town, and another at Hessen Ford.   There is some difficulty in correlating this latter with the limestone of Milladon and St. Germans; but the beds at South Bake dip westerly, and it appears that some disturbing influence has been in operation in the vicinity.

If, however, we take the section up the Looe river a little further to the west, we find the grit beds and limestone of the town of Looe succeeded by a long downward succession of argillaceous slates, which are occasionally calcareous, as in Common Wood, at the pools opposite Trenant, at Terrers Pill, where we have the continuation of the Polpever limestone, and at the bridge at the foot of the ascent to Duloe.   The section is not consecutive, and there are intervals, where no rocks are exposed, wide enough for concealed reversals of the dip to occur; but we miss from the series the gritty bands and reddish arenaceous slates so abundant between the base of the Hessingford limestone and the coast.   Amid rocks, however, in which grits appear so irregularly, this circumstance loses much of its importance.

If we follow the strike of the calcareous beds south of St. Stephens by St. Germans to Milladon, and thence to Tredinick and Tremain, we have the northern limit of a group of beds which occupies the interval between the volcanic rocks of Saltash and the Plymouth limestone, deflected round to the south-east as we advance towards the Looe river, by, as I believe, the upheaval of lower rocks between Duloe and St. Keyne; and although, in the section of the argillaceous rocks of the Looe river, folds and repetitions of the beds may escape observation, there cannot be much ambiguity about the dip of the beds along the coast of Whitesand Bay, where the bedding is rendered clear by the seams and bands of interstratified grit.   This belt of rocks, which on the Hamoaze occupies an interval of no more than about two and a quarter miles when followed to the Looe river, widens out to nearly three times that distance.   This appears to be due partly to the lowering of the angle of dip, and partly to the addition of arenaceous materials which have come in from the south-west or south; at the same time there is the possibility of some concealed repetition of the beds between the Lyhner river and the coast.

The attempt to determine the relations of this belt of rocks west-

ward of the Looe river is not unattended with difficulty. It has been already stated that a fault extends from the west of Bodmin, by Lostwithiel, towards the coast. A second fault trends from the mining-district of Pembroke across the Gribbin promontory to Combe Hawne, near the mouth of the Fowey. This latter fault has thrown up the country on the north, and brought up at Pencarra Head, Fowey, and Tywardreath the rocks which passed down at Tredinick, Tremain, and St. Veep, forming a synclinal trough which contains the fossiliferous rocks of the Looe river, together with some red and variegated argillaceous beds which range up from the coast at Talland, by the north of Lansalloes and Gregon, across the Fowey, towards Tywardreath. These red slates appear to be a continuation of those which, trending down from Polbathick, become partially reddened at Narkurs and Treliddon, and reach the coast at the mouth of the Seaton river; and if the upcast of the coast-line between Talland Bay and Gibbin Head is not entirely due to the fault already noticed, but is partly owing to an anticlinal axis out at sea, south of Polperro, it is not impossible that such axis may curve round, parallel with the belt of variegated slates, and strike the coast of Whitesand Bay at St. Germans Beacon, accompanied by inversion of the strata, and terminate in the bed of the Lyhner north of Anthony. In that case, the grits of Sheviock Wood would be the same as those of Carracawn Cross, with the slates of Polbathick folded in between them.

Notwithstanding the apparent contrariety of the dips, and the consequent difficulty of obtaining satisfactory evidence, I believe that the argillaceous rocks of Lanreath and the north of St. Veep rise up from beneath the fossiliferous and purple slates on the south, and overlie the gritty beds of Boconock. Looking to the general structure of the country, and to the manner in which the slates with ash-beds of Saltash and St. Germans are carried north-westward by Liskeard and St. Neots, rising up over lower rocks on the one hand, while the calcareous and argillaceous rocks that overlie them are curved southward across the Looe river to the mouth of the Fowey on the other, it appears more consistent with probability that the grits and thick slates associated with them are lower rocks broadly elevated rather than higher beds troughed in a shallow basin. In mineral character they resemble those of the Bodmin district, and appear to be the same disturbed in their line of strike by the Lostwithiel fault, and have no resemblance petrologically to the higher rocks of the Plymouth country. Moreover the slates of the mouth of the Fowey, and of the coast thence to Polperro, which support the red rocks on the north, contain *Pteraspis Cornubicus*, M'Coy, which has been found also in the slates of Cliff on the Fowey, and in the vicinity of St. Veep; it occurs likewise on the same line of strike in the calcareous slaty rocks at Milladon, near St. Germans[*].

The fossiliferous slates of Saltash and St. Germans, with their included volcanic ash-beds, brought down from the north-west by

* For a different interpretation, see De la Beche, Rep. pp. 80, 81.

repetitions oblique to their line of strike, join on the Hamoaze with the argillaceous rocks of Polbathick and Anthony, and range eastward by the south of Egg Buckland to Hamerton Ball and the vicinity of Ivy Bridge, where they are broken through by the granite of Harford.   Much of this slate is red or claret-coloured, especially in the vicinity of Keyham, Stoke, and Ford Park ; and the gritty bands associated with them further to the west appear to have entirely thinned out before reaching the Hamoaze.   To the eastward of Ivy Bridge and the granite, the beds curve to the north-east, resting on the volcanic rocks of South Brent, which are altered by the granite ; and they include, on the same line of strike, as we advance to the north-east, other bands of igneous rock, together with the limestones of Buckfastleigh, Ashburton, Bickington, and Ash Hill.   These limestones dip to the east and south-east, at angles varying from 15° to 20°, but they are much broken by north-west and south-east faults.   The slates on the west of the limestone are uniformly argillaceous, and often very evenly laminated, and appear everywhere to dip under the limestones.   The manner in which these lower rocks are brought against the Culm-measures has been already described, as also the position of the beds west of Ashburton, which, near the town, dip towards the volcanic rocks and limestones ; but at Horsehill and at the corner of the lane leading up to the Druids' Farm they are thrown over to the north, beyond which the bedding appears to be nearly vertical ; and they contain *Spirifera disjuncta, Petraia bina, Athyris concentrica, Chonetes sordida, Orthis interlineata,* and a species of *Cyathocrinus* ; and in all probability these light-coloured beds, thus thrown under the Culm-measures, may not be very far below the base of the limestones.

As we follow the slate-beds westward of the southern extremity of the granite at Ivy Bridge along their line of outcrop to the north-east, they become less and less inclined, as seen in the railway-sections between Ivy Bridge and Totnes ; the lower beds, as they range northward, follow the course of the volcanic rocks and limestones of Dean Church, Buckfastleigh, Ashburton, and Bickington, dipping to the east and south-east at angles which do not average more than 12° or 15°, and seldom exceed 25° ; while the higher beds pass by Black Hall, near New Bridge, on the Avon, where they are fossiliferous, to Sandwell, and thence to Dartington, north of Totnes.   Thus the belt of rocks opens out, and the beds, being thrown down more or less horizontally by the faulting on the north-west of the Ashburton range of limestones, undulate broadly over the country towards the coast at Torbay, supporting the limestones of Dartington, Berry Pomeroy, Marldon, Ogwell, Kingskerswell, and Torquay, and the minor patches of Sandwell, Paytor, Woolstone Green, &c. Although occasionally purple, the beds are less frequently so than they are further to the westward, and grit bands appear to be absent.

The evidence of the superposition of the slates to the Ashburton limestones appears to be free from ambiguity, notwithstanding the faults which cross the beds on the line of strike.   The limestones

occupy, for the most part, the low ground, and dip into the hills on the east and south-east, which are composed of slates and ash beds dipping in the same direction, and rising steeply 200 feet or more above the limestones. This is well seen at Pridhamsleigh, in the descent to Ashburton from Goodrington, and in the hills north of Bickington, where the limestone is overlain by volcanic rocks. Even supposing, therefore, that the lamination does not represent the true bedding, it will still appear that the slates are uppermost.

The relation of these slates to the overlying limestones will be considered in connexion with the latter.

2. *Plymouth and Torbay Limestones.* — The Plymouth mass of limestone commences on the west at Impacombe, south of Devonport, where it is overlain by the slates and red rocks of Mount Edgcombe ; and slates, for the most part blue, pass under it on the north ; but its relation to the rocks on the west is obscured by the waters of the Hamoaze and Sango Lake. I am unable, therefore, to bring this limestone into connexion with the contorted beds of St. John's, among which, as already noticed, there are some calcareous slates ; but the higher beds of Impacombe appear to run out seaward by Millbrook and Withnoe, above the purple and greenish slates of Freathy, which include some bands of volcanic ash. It is the same with its eastern termination, which appears to thin out horizontally or nearly so. As observed by Sir Henry De la Beche, however, there is much ambiguity about the bedding of this limestone, although the general dip of the mass is to the south, so that its relations and thickness are difficult to ascertain. The joints are very regular, and in places where the rock is highly crystalline the true bedding is very obscure. There can, however, be little question that the limestone overlies the variegated slates of the north of Plymouth, and dips under the grey and blue slaty rocks of Mount Edgcombe, Plimstock, and Elberton ; and between its outcrop and its dip under the higher rocks, it appears to form one or more undulations, so that its real thickness may be very much less than its superficial breadth and apparent dip would seem to indicate.

In following the line between the slates which underlie and overlie the Plymouth limestone to the eastward, we are assisted by the volcanic rocks of Hearston and Filham House, which lead up to the fossiliferous slates of Black Hall on the Avon. No limestone, however, occurs on this line of strike until we reach Sandwell, where there is a small patch overlain by volcanic rocks ; and beyond this we have the somewhat larger patch of Paytor, which is brought down by a fault bounding it on the north ; and apparently the limestone of Woolstone Green is also faulted down. There is a fourth small patch at West Ogwell, which together with those just named appear to form the thin western margin of the range of limestone, which becomes more largely developed immediately to the eastward of them. The great mass south-west of Newton Bushell, which constitutes the Ogwell and Ipplepen limestone, forms a tableland of slightly undulating beds, denuded and excavated in the vicinity of East Ogwell and in the valley of the Torbryan brook, so as to

expose the underlying beds, which at the former locality consist in part of volcanic ash. On the east of Ogwell this limestone is overlain by Culm-measures, as already stated when describing these Carbonaceous rocks, thrown down apparently against the nearly vertical limestone of Connator, on the east, by a fault. Three other small masses of limestone are seen to the north-east of Connator, one of which, near Woolborough Church, has afforded a fine series of organic remains, many of which are quite local[*].

On the east of the Ogwell and Ipplepen limestone the lower slates are faulted up, and form high ground about Dainton School-house, and between the school and Whitborough on the east. These slates throw off the limestone of Kings Kerswell on the north, which dips under some higher slates at the village, and the limestone of Bulley Barton on the south. This latter appears to be the northern edge of the Marldon mass exposed from beneath the overlying New Red sandstone and conglomerate, the small protrusions of Compton, Combe Fishacre, and the narrow outcrop at Battleford showing their connexion beneath ; and, the upcast on the east of the limestone of Ipplepen being much less than it is at Dainton School-house and the Two-mile Oak, the two limestone masses at Bow Hill are brought nearly into contact, a thin strip of slates only intervening. These slates dip to the south-east under the limestone of Bulley Barton as it curves round by Bow Hill, the Ipplepen limestone dipping against them. The mass of limestone which protrudes through the Trias at Compton, together with two other small protrusions at Gallows Gate, connect in a similar manner the Marldon limestone with that of the Torquay district ; and this, again, has its deep-seated connexion rendered probable by the protruding mass south-west of Deccombe. The limestone of Kings Kerswell is manifestly a portion of that of Ogwell, separated only by the slates thrown up by the fault which bounds the Ogwell limestone on the east, as are likewise the smaller masses of Connator, Woolborough, &c., which occupy the faulted ground south of Newton Bushell.

The Torquay limestone need not detain us, as it is well known and has been described in detail in a special paper by the late Sir Henry De la Beche[†]. An anticlinal axis extending from Upton to the coast at Meadfoot Sands brings up the lower beds, which here contain some grit beds, resemble some of the equivalent beds of Whitesand Bay, and contain many of the same fossils as those from the Looe district—among others, *Pleurodictyum problematicum, Athyris concentrica, Spiriferina cristata, Leptæna laticosta, Orthis hipparionyx, Bellerophon bisulcatus,* &c. In the cliff between Meadfoot sands and the Thatcher rock two fine scales of *Phillolepis concentricus,* Ag., have been found by Mr. Pengelly, and are now in his

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[*] I had an opportunity of spending a day in examining the rocks in this vicinity with Mr. Beete Jukes ; and the conclusion we arrived at was, that the rocks to the east of the turnpike-road were not Culm-measures as they are coloured on our maps.

[†] Trans. Geol. Soc. 2nd Ser. vol. iii. p. 161.

collection ; and a scale from Meadfoot is figured by Prof. Phillips (Pal. Fos. pl. 57. f. 256), and referred to *Holoptychius*, which has also, judging from the figure, very much the appearance of *Phillolepis*.

It is less easy to ascertain the relations of the limestones to the north and east of Totnes, although there is no reasonable cause for supposing that these calcareous masses are other than portions of the same range of limestones. This arises partly from the extreme difficulty there is in getting reliable evidence respecting the dip of the beds, as much of the limestone exhibits no true bedding, and the lamination of the slates cannot always be relied upon.

The limestones do not afford much assistance. It is frequently extremely difficult to distinguish the bedding from the often very regular joints and planes of cleavage ; and a bed of fossiliferous rock included between others that are devoid of fossils will sometimes show a true dip quite at variance from the apparent one. Moreover the limestones are sometimes much fractured and contorted ; and in that case very little reliance can be placed upon a few local observations, which may yield very conflicting results. The junk-like termination of some of the limestones is another source of perplexity, their relation to the slates being such as to make it appear that, in the movements to which the rocks have been subjected, the limestones have been, as it were, dislocated from the slates, so that the former are bounded by what are virtually lines of fault.

It would appear, however, that higher rocks, which occupy a synclinal trough that trends up from Plymouth Sound by Halberton to the vicinity of Totnes, are thrown down by faults, one of which runs up from Sandwell Park, by Whiteley and Colt, to the Dart south of Dartington House, and is continued thence across the railway south of Forder Bridge, and another, skirting the limestone of Boston, is continued N.N.W. towards Bow Barn. The result of this downthrow has been to push the southern extremity of the Dartington limestone round to the north-west, and the Barton and Bunker Hill limestone to the eastward. The evidence of the former fault is to be seen in proceeding along either of the turnpike-roads from Totnes to Skinners Bridge. We there find similar thick slates to those which occupy the country between Totnes and Ashsprington, to be continued nearly to Colt with a south-easterly dip ; but at Colt the dip of the slates conforms to that of the overlying limestone at Skinners Bridge, and is to the north-west. A third fault follows the bed of the Dart from Totnes to the south of Allabeer—the thick slates which strike up to the river at right angles to the stream with a southerly dip abutting against thinly laminated argillaceous slates which, with a variable dip more or less to the eastward, occupy the low ground on the opposite bank, near Weston. This fault carries the country on the east of the Dart somewhat to the southward. Another fault, extending from Longcombe Cross to True Street, bounds the limestone of Berry Pomeroy on the south. The limestone dips to the north, while the red slates on the south of it dip in the contrary direction

under the higher limestone of Longcombe, which, associated with some volcanic ash, ranges by Great Court and Howell towards the limestone of Boston.   Other faults exist, some of which have been laid down on the map.

This faulting, or rather the force which produced it, has so contorted and fractured and, as already stated, so dislocated the limestones, that it is very difficult to distinguish in this neighbourhood the slates which were anterior from those which were posterior to the period of the limestone*.

The dip of the Dartington limestone, from the south of Staverton round by Skinners Bridge to Vineyard, is inward towards Dartington House as a centre.   In the quarries at the two last-named localities the bedding is more than usually clear.   South of Dartington, however, the outer edge of the limestone is thrown over and dips to the south-east.   The two limestone masses on the opposite side of the Dart, the one west of Buckyatt, the other west of Little Hempston, are the continuations of the Dartington limestone faulted off.   The former rests on volcanic rock, which has not altered it, and is overlain by slates with some ash bands dipping to the south-east. These rocks, therefore, are above the limestone, and presumably those also of Dartington House, as the limestone dips towards them. The other mass of limestone, west of Little Hempston, is traversed by a fault along its line of strike, which is continued on to the railway-cutting below Forder Bridge.   This fault has brought some volcanic rock against the limestone on the west, while the slates on the east of the limestone dip off it towards Little Hempston.   South-east of the village there is another faulted strip of limestone, the northern portion of which dips to the south-east at a high angle, while the southern half in the quarry and railway-section dips north-west towards the church.   It appears, therefore, that all the slaty rocks between the Buckyatt limestone and that of Bunker's Hill and Gatecombe House are above the limestones ; but it is not clear how they end to the north-east ; there are, however, some appearances of a fault running north-west and south-east by Forder Bridge ; and the dip of the Fishacre limestone, which appears to be the continuation of that west of Buckyatt, is reversed.

The mass of limestone extending from Boston, by Bunker's Hill, to Gatecombe House, appears to be thrown up by a fault ; but there is great uncertainty respecting the relations of the slates on the west between Bunker's Hill and Berry Pomeroy, the dip of the lamination in the slate being often quite at variance with the bedding of the limestone.   The same want of accordance between the bedding of the limestone and the lamination of the slates is again observed at Arton.

The lower slates and limestones are again brought up to the sur-

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* Sir Henry De la Beche appears to have considered that these limestones may have had " their geological continuation consisting in slate." It is difficult, however, to fall into this view, seeing that the limestones are for the most part devoid of detrital materials, and would appear therefore to have been formed in waters free from muddy sediments.   *Vide* Rep. p. 72.

face between Ash and Higher Yalberton on the north, and Sharkham Point, near Brixham, on the south. The great mass of limestone of Berry Head, which stretches inland to Walton, and of which the Yalberton and Stoke Gabriel limestones are but detached portions, forms an arch, which is depressed in its central portions between Walton and Fishcombe Point : while its southern margin is thrown over an anticlinal axis at Mudstone Sands, and is seen at Sharkham Point and Brixham dipping under the higher beds on the south, its northern edge, between Higher Yalberton and the coast, is doubled under with inverted dip. The Stoke Gabriel limestone is thrown up on the north-east by a fault, which extends from the village by Howell to the south-west of Ash, and has brought it against the higher beds which range up from Ashsprington. On the north, this limestone dips under the purple slates and grits of Windmill Hill, and near Higher Yalberton some slates are troughed in a fold of the limestone.

A long narrow anticlinal axis commencing at Yealmpton ranges by Broadway and Cornworthy, and thence to Brixham, where at Mudstone Sands it appears to be again narrowing to a termination ; and a second anticlinal axis to the north of the former commences near Ludbrook and runs, by the north of Roster Bridge and between Perchwood and Tuckenhay, to the south-east of Stoke Gabriel. These anticlinal axes have brought up the lower slates with an overthrow to the north. If we follow the line of strike between the fossiliferous slates and the base of the overlying limestone from Brixham past Lupton House to the limestone of East Cornworthy, and thence to Middle Washburton and the Avon below Broadly and the north of Modbury, to the limestone of Palmer's Cross, which is clearly on the same line of strike as that on the south side of the anticlinal axis at Yealm Bridge,—and again in an opposite direction through Ermington and the limestone of Shilstone to the Avon at Beckham, and thence back by Fowlescombe to Ludbrook, and again from Ludbrook by North Hewish, Diptford, Harberton Ford, and Perchwood to the west of Stoke Gabriel,—such line will indicate pretty nearly the limit between the upper and lower slates, and the place of the Torbay limestones, which, however, in the part of the country between Totnes and the Yealm, are only feebly represented at a few points.

The limestone at Yealm Bridge is partly dolomitized. It forms the crest of the anticlinal axis, but is depressed on the south towards Torr. On the north it is underlain by a bed of volcanic rock, from off which it has been partly removed by denudation, the thinner edge at Ketley and the small patch on the north side of the axis at Yealm Bridge alone remaining.

There still remain to be noticed the several masses of Devonian limestone which protrude through the Culm-measures on the north-east of the Bovey basin ; but there is no apparent reason for separating any of these masses from those of Ogwell and Kings Kerswell. The Chudleigh limestone has been already noticed when describing the Carbonaceous rocks, and perhaps from its position it might be regarded as belonging to the Ashburton range ; but the fossils

associate it rather with that of Ogwell. The slates on either side of the Teign estuary are Devonian, and apparently they rise from beneath the limestone; but there is much difficulty in ascertaining this with certainty. They are entirely argillaceous, and in part red or claret-coloured, and are altered by the igneous rock at Colway Cross, which seems to rest upon them.

The fossils of these limestones are so well known by the lists of Phillips[*], Godwin-Austen[†], and Sedgwick and Murchison[‡], that it is not necessary to enumerate them here. In the subjoined Table will be found the local distribution of the species which have been hitherto met with in the slates which immediately underlie these upper limestones of the south-east of Devon; but it is very far from complete, as the several localities, as well as some others not mentioned, have not by any means been thoroughly searched. The species from the vicinity of East and West Ogwell are given on the authority of Mr. Godwin-Austen[§]; the rest are from the 'Palæozoic Fossils' of Professor Phillips, and other sources[||].

TABLE I.

Species occurring in the beds immediately below the Upper South-Devon Limestones.

Species.	Localities.				
	East & West Ogwell.	Newton Bushell.	Meadfoot.	Mudstone Bay.	Black Hall.
Favosites dubia, *Blainv.*	...	...	*		
—— fibrosa, *Goldf.*?	...	...	*		
Alveolites suborbicularis, *E. & H.*	...	...	...	*	
Petraia Celtica, *Lonsd.*	*	...	*[7]	*	
—— pleuriradialis, *Phill.*	...	...	*		
Pleurodictyum problematicum, *Goldf.*	*	...	*	*	
Cyathocrinus megastylus, *Phill.*					
—— pinnatus, *Goldf.*	...	...	*	*	
—— nodulosus, *Phill.*	*				
Cheirurus articulatus, *Salt.*	*				
Homalonotus elongatus, *Salt.*	...	...	*		
—— armatus, *Burm.*?			*[7]		
Phacops granulatus, *Münst.*	*				
—— punctatus, *Stein.*	*				
—— lævis, *Münst.*	*	*[2]			
—— latifrons, *Bronn.*	...	*[2]	...	...	*[3]
Fenestella antiqua, *Lonsd.*	*				
Hemitrypa oculata, *Phill.*	...	...	*		
Retepora repisteria, *Goldf.*	...	...	*	*	
Athyris concentrica, *V. Buch*	...	...	*		

[*] Pal. Fos. p. 142.   [†] *L. c.* p. 466.   [‡] *L. c.* p. 703.
[§] *L. c.* p. 469.
[||] This Table must be taken in connexion with Table III, which gives the distribution of species in the corresponding rocks in a different area, and together include, I believe, all the recorded species on this horizon.

Species.	East & West Ogwell.	Newton Bushell.	Meadfoet.	Mudstone Bay.	Black Hall.
			Localities.		
Spirifera undifera et var. undulata, *Ræm.*	...	...	*[4]		
—— lævicosta, *Val.*	*[7]				
—— speciosa, *Schloth*	*				
—— disjuncta, *Sow.*	*[7]				
Spiriferina cristata, var. octoplicata	...	...	*[4]		
Rhynchonella pleurodon, *Phill.*	...	...	*[4]		
Atrypa reticularis, *Linn.*	*[7]				
Pentamerus brevirostris, *Phill.*	*[7]				
Rhynchonella cuboides, *Sby.*	...	...	*		
Strophomena rhomboidalis, *Wahl.*	*[7]	...	...	...	*[5]
Streptorhynchus umbraculum, *Schloth.*	...	...	*[4]		
—— gigas, *M'Coy*	*[7]				
—— crenistria, *Phill.*	...	...	...	...	*[5]
Leptæna laticosta, *Conrad*	...	...	*		
—— interstrialis, *Phill.*	...	...	...	...	*[5]
Orthis hipparionyx, *Vanux.*	...	...	*		
—— resupinata, *Mart.*	*[7]				
—— granulosa, *Phill.*	...	...	*	*	
Chonetes sordida, *Phill.*	*	...	*		
—— simiradiata, *Sow.*	...	...	*[6]		
—— Hardrensis, *Phill.*	*[7]	...	*	...	*[5]
Aviculopecten polytrichus, *Phill.*	...	...	*?	*	
Pterinea anisota, *Phill.*	...	...	*		
—— subradiata, *Phill.*	*[7]				
Clidophorus ovatus, *Phill.* non *Sow.*	...	...	*		
Modiola scalaris, *Phill.*	*				
Pleurotomaria aspera, *Sow.?*	*[7]				
Trochus Boneii, *Stein.*	*				
Euomphalus serpens, *Phill.*	...	...	*		
Bellerophon bisulcatus, *Röm.*	...	...	*		
Porcellia Woodwardii, *Sow.*	...	...	*		
—— striata	...	...	*		
Orthoceras tentaculare, *Phill.*	...	...	*		
Cyrtoceras bdellalites, *Phill.*					
Phillolepis concentricus, *Ag.*	...	...	*[3]		
Scale of Holoptychius?	...	...	*		
Pteraspis (Scaphaspis) Cornubicus, *M'Coy*	...	...	*[3]	*	
Cephalaspis? Carteri, *M'Coy*	...	...	?		

[1] Murchison.   [2] Salt. Mon. Pal. Soc.   [3] Pengelly.   [4] Davidson.
[5] Davidson, in Col. Pengellii.   [6] Salter.   [7] Jermyn-Street Museum.

3. *Beds overlying the Plymouth and Torbay Limestones.*—It has been already stated that a long narrow inclined synclinal trough extends from Plymouth Sound to Tor Bay. The beds contained in this trough consist of argillaceous slates similar to those which underlie the limestones north of Devonport. They are well seen on the coast at Jenny Cliff Bay between Mount Batten and Withy Hedge, of which a section has been given by Prof. Phillips*. South of Plimstock and Elburton this belt of rocks widens out to pass on

* Pal. Fos. p. 201, Nos. 3 to 5 inclusive,

both sides of the Yealmpton limestone ; and it contains much dark-blue slate, and occasionally, as at Gooswell, some calcareous bands. These blue slates occupy the middle of the trough, and are quarried near Brixton and north of Ludbrook, &c.   At Harberton the trough deepens, being thrown down on the north as already described, and higher beds occupy the interval between this place and the Dart. These latter consist of thick slates in which much volcanic matter is disseminated, interstratified with bands of grit ; and for the most part they yield a red soil.   Volcanic rocks are frequent ; and on the east of the Dart there are some calcareous bands associated with them, as also much red and purple grit.   Good sections of these rocks are to be seen in the vicinity of Totnes and in the descent to Bow Bridge ; and the manner in which they have been brought into relation with the limestones of Dartington, Boston, and Berry Pome-roy has been already explained.   The continuation of these rocks across the Dart is somewhat interrupted by the upthrown limestone of Stoke Gabriel, and by the southern portion of the Berry Pomeroy limestone, which is similarly thrown up at Longcombe Cross.

The variegated argillaceous slates (partly claret-coloured) which form the lower portion of this upper group rest upon the limestones of Berry Pomeroy, Arton, Loventor, and Marldon ; and immediately above the limestones they are occasionally fossiliferous, as in Berry Park ; but they have yielded little that can be determined, and the species do not appear to differ from those contained in the slates below the limestones.   These beds dip to the east and south-east, and pass under the purple and greyish grits of Blagdon Cross, Beacon Hill, Ockham, and Cockington ; while the beds thrown off the Stoke Gabriel and Yalberton limestones dip to the north under the grits of Windmill Hill and Collaton, thus forming a shallow basin which is occupied by the Triassic rocks of Painton.   Much of the red colour appears to be due to the action of the atmosphere upon the bases contained in the rock, and beds which are light-coloured often yield a red soil ; but the blue slate appears especially liable to become claret-coloured.

The rocks thrown off on the south of the anticlinal axis extending from Mudstone Bay to Yealmpton are precisely similar to the lower beds contained in the above-mentioned synclinal trough, and consist of grey and dark-blue argillaceous slates, the latter often changed to a purplish or red colour.   These rocks are well seen in the railway-sections east of Greenway House, where they contain some beds of ash.   From Greenway they are continued by Ditsham and Combe, where they have been quarried for slates, and by New House, on the Avon, to Modbury, and thence south of the Yealmpton limestone to Staddiscombe, near Plimstock, and to the coast at Withy Hedge in Plymouth Sound.   Above these are beds of slate, much of which is reddish, containing bands of grey, yellowish, or purple grit.   These grits, apparently, do not form continuous beds ; at least they cannot be followed many miles on their line of strike.   The following section is seen on the Torquay and Dartmouth railway between the tunnel at Greenway Farm, south of Galmpton, and the station at Kingswear.

Section from the Tunnel at Greenway House to Kingswear.

Feet.

1. Volcanic ash resting on grey glossy slates sparingly fossiliferous . .
2. Grey and bluish-grey slates (corresponding to viaduct) . . . . .
3. Purplish and greenish evenly laminated glossy slates. Dip S. 30°
    E. at 25° 200

Crush and contortion—perhaps a line of fault.

4. Purplish and greenish glossy slates. Dip. S. 30° E. at 35° to 40°. . 160
5. The same, disturbed, and not truly *in situ* 160
6. Interval covered with vegetation—apparently slates with grit bands . 550
7. Red and greenish flags and grits, partly thick-bedded. Dip S. 20° E. . 250
8. The same, not *in situ* 90
9. Red and greenish flags and slates with thick beds of sandstone.
    Dip S. 20° E. at 35° 300
10. The same, tumbled about and not seen *in situ* 400
11. Red and greenish grey slates and grits, greatly folded and contorted . 260
12. Red slates and flaggy sandstones 60
13. Light-coloured and reddish slate 140
14. Reddish and brownish slates, with beds of sandstone much contorted
    and folded, the general dip being southerly at about 15° 470
15. Hard, coarse, and often reddish slate. Dip S. 20° E. at 50°, about . 350

Viaduct.

16. Soft grey slates. Dip S. 20° E. at 50° 180

Viaduct.

17. Light-grey slates, with numerous small quartz veins. Dip S. 30° E.
    at 35° 1240
18. Grey evenly bedded slates, dipping at an angle of 45° (opposite em-
    bankment) 370

"Floating Bridge."

19. Light-grey slates. Dip S. 30° E. at 25° to 35° 100
20. Volcanic ash 55
21. Soft greenish slates 90
22. Blue slates. Dip S. 30° E. at 30° (opposite embankment) 160

Fault.

23. Grey slates 110
24. Quartz vein 4
25. Slates, chiefly bluish grey, much veined with quartz. Dip S. 40° E. at
    45°, but undulating and wavy 360
26. Grey thick-bedded sandstone. Dip S. 30° E. at 30° *90
27. Blue, grey, and purple slates, with purple and grey grits, much undu-
    lated and contorted. General dip S. 30° E. at angles varying from
    12° to 45° (opposite embankment), about 200
28. Hard grey and bluish slates, sometimes reddened; somewhat glossy and
    micaceous on the surface, and much veined with small quartz veins,
    and occasionally including thin bands of grit. Dip S. 20° E. at 45°,
    about 1200

Bridge.

29. Hard reddish slightly micaceous slates with a few calcareous seams.
    Encrinites. Dip S. 20° E. at from 35° to 45° 250

Kingswear Railway Station.

These gritty bands come to the coast at Man Sands and Scabba-
combe Bay. If we follow the arenaceous rocks on the north of the
"Floating Bridge" to the westward we find them to range by Little
Combe, and by Tidaford and Woolcombe to Collaton, Morleigh
Down, Black Down, and Lee Moor, and then to curve south-west
by Stubston, Sherlangston and Torr, to near the mouth of the Erme.

* The above figures refer to the distances along the railway, measured by the
intervals between the sleepers, which was 10 feet, and not to actual thicknesses.

If in like manner we follow the more southern belt of arenaceous rocks from the north of Kingswear, we find purple and grey grits south of Ditsham Cross at Bugford and south of Blackauton; and hard reddish slates, similar to those at Kingswear, occur on the same line of strike at Loddeswell and Hatch Bridge; and with these slaty and arenaceous beds are associated some bands of a peculiar volcanic rock consisting of felspar and a foliated greenish mineral resembling chlorite.   These two belts of rock, therefore, become separated, west of the Avon, by argillaceous slates which occupy the country between Heathfield and Aveton Giffard, and between Kingston and the mouth of the Avon; and as they dip under the beds which strike up from Loddiswell and East Allington to Aveton Giffard and Bigbury, we must presume that they are lower beds brought up; but in what manner is not very clear.   With the grit-beds which strike down to the mouth of the Erme from Heathfield Down there is some rock composed of quartz and felspar; but I did not meet with this rock *in situ*, although heaps of it were lying by the roadsides, and I was unable, therefore, to ascertain its character or relations; but the rocks on the east of this band of quartz and felspar at Bednick, Broom Hill, and Wakeham dip south towards a mass of igneous rock, which at the quarry at the eastern extremity of the mass appeared to be a bedded rock, dipping south and graduating upwards into the slates above.   The variegated argillaceous slates, which underlie the grits of Black Down and Lee Moor, widen out as they trend round by Modbury, and with a lessened angle of dip, and probably some undulation, range by Holberton towards Newton Ferrers, and occupy the whole of the country between the Yealmpton limestone and the coast.   It would almost appear, therefore, that some line of fracture extends up from near the mouth of the Erme towards Heathfield Down, and has cut out part of the belt of arenaceous rocks which ranges up from Morleigh Down and Lee Moor on the east.

It is difficult to bring the argillaceous rocks on the east of the Yealm satisfactorily into connexion with those on the west of the river, without supposing a line of fault to run up the stream from the coast south of Worswell.   The beds which range down from the south of Holberton appear to run out to sea at Stoke Point, and the grits which strike down to Erme mouth were not met with again on the east of the Yealm.   Light-coloured grits, however, occur in the hill north of Knighton; but it is not certain that they are a continuation of those of Staddon Point, although only grey and blue slate was met with between the grit at Knighton and the limestone at Plymstock, without any appearance of the red grits of Staddon Point.

These grey and blue slates strike up from across the Yealm south of Kitley Park, and from the north of Brixton, and appear on the shores of Plymouth Sound between the limestone and Withy Hedge, and contain some calcareous bands, especially near Gooswell.   To the south of these are the red grits and slates of Staddon Point, which range inland to the south of Staddiscombe *, and, if continuous with

* No. 6 in Prof. Phillips's section, *l. c.* p. 201.

the grits of Knighton, must curve round to the south-east; but if they do so, the dips in the argillaceous rocks of Down Thomas and Longdon must be deceptive. The red grits of Staddon Point are much folded, and some of the beds inverted, but the general dip is southerly; and above them are the grey and bluish slates, with thin grey grits, of Bovey Sand Bay; and these are succeeded by reddish slates, partly argillaceous and partly hard and micaceous, like those of Kingswear. The general appearance of these rocks along the shore of Plymouth Sound reminds one of the section on the Dart river.

These rocks are continued across Plymouth Sound without any material variation. The argillaceous slates which overlie the limestone at Mount Edgecombe correspond to those of Jenny Cliff Bay, but west of Millbrook they become interstratified with bands of grit. Red arenaceous rocks like those of Staddon Point succeed these at Marker Church, and are continued southward as far as the Barracks, where a mass of reddish felspathic rock * separates these grits from the grey slates of Kingsand and Cawsand. This mass of igneous rock appears to have carried the grits somewhat to the north of the general line of strike; but the latter are not continued across the promontory to Whitesand Bay in exactly the same mineral condition, their place on the coast being occupied by coarse slates with thin grit-bands. The rocks of Kingsand and Cawsand are similar to those of Bovey Sand Bay; and similar rocks, sometimes reddened, are continued to Penlee Point and the Rame Head. The dips are all southerly, at angles varying from 35° to 45° or more.

Returning to the Kingsbridge promontory, we find coarse reddish slightly micaceous slates, similar to those of Kingswear, extending all along the shores of Start Bay, from the mouth of the Dart to Slapton Bridge, dipping southerly at angles varying from 30° to 60° or more. On the west, on the other hand, soft argillaceous grey, blue, or purple slates occupy the whole of the distance between Aveton Giffard and the metamorphic rocks at Hope. At Aveton Giffard there are some blue and green evenly laminated slates, the laminæ of which dip S. 20° E. at 70° or 80°; and to the south of these a long belt of argillaceous rocks, apparently an anticlinal axis, which includes a band of similar roofing-slates, ranges about N. 10° E. from the coast between Rigmore and the mouth of the Avon, past Churchstow, to Buckland Tout-Saints and Netherton, and thence towards Coles Cross and Heathfield. In an opposite direction coarse reddish slates, mingled with others that are more argillaceous, but for the most part red, trend westward from the north of Slapton by Hartston, to the grit beds of Marlston, north of Sherford, and thence to Kingsbridge. All these beds dip to the south at high angles; but along a line extending from Hurleston by the north of Charleton and Stokenham to Slapton Sands the dip becomes reversed, and the beds rise to the south; and with them a band of dark bluish-grey roofing-slate, similar to that of Buckland Tout-Saints, and Netherton, which crops out along a parallel line crossing the Kingsbridge inlet south of Charleston, and strikes thence by Frogmore to the south

* Apparently intrusive.

Fig. 5.—Section from the Granite North of Ugborough to the Kingsbridge Inlet at Salcombe.

N.

Ugborough.   Lee Moor.   Avon River.   Churchstow.   W. Alvington.   Charleton.   Salcombe.

e. Metamorphic Rocks.

d. Upper South-Devon Slates and Grits (d).

g. Torbay Limestone.

c. Upper South-Devon Slates.

f. Volcanic Rocks.

b. Lower South-Devon Slates.

a. Granite
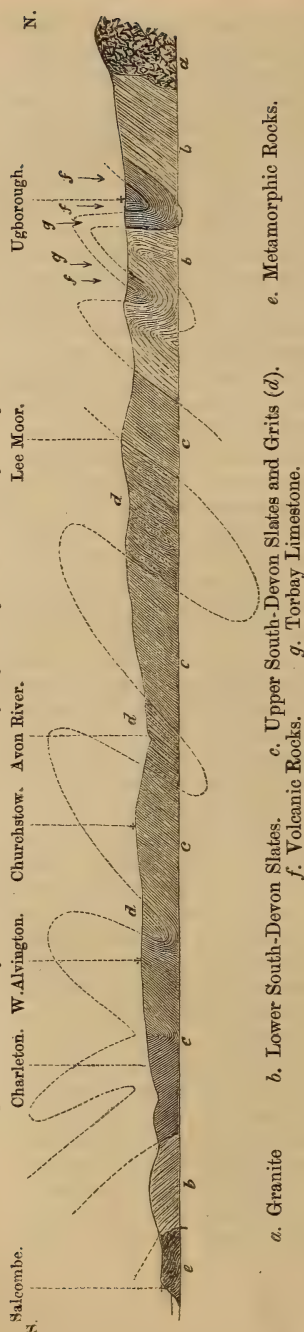
of Torr Cross. Other slates, not very dissimilar except in their less even lamination, succeed these, with the same northern dip, and lead up to the metamorphic rocks of Salcombe and the Bolt.

The relation of the soft variegated argillaceous rocks to the somewhat coarser and less regularly laminated reddish slates on the shores of Start Bay north of Slapton is a question not very easily decided, except inferentially, which, of course, is not the most satisfactory method. But the reddish slates of Start Bay precisely resemble those at the southern extremity of the Dart-river section at Kingswear, to which they appear to form a consecutive series; and if we trust to the dips as representing the true succession of the beds, they will appear to be clearly above the grits of the Dart river opposite Dartmouth, and of Bugford. The variegated slates on the west, between Aveton Giffard and the altered schists of the Bolt Tail, on the contrary, resemble those which are seen to pass beneath the grits on the north at Modbury, and at the viaduct near Greenway House on the Dart. Following the strike of the beds from Dartmouth by Woodleigh and Aveton Giffard to Regmore, and from Stokenham to Thurlestone, we find that the included rocks occupy on the shores of Bigbury Bay not more than half the breadth of country that they do on the opposite coast south of the Dart; and therefore it would appear that the sharp anticlinal axes are on the west, and the synclinal axes on the east. As the dips are all southerly (from S. to S. 20° E.), at high angles, these axes must be thrown over to the north, and we thus have the same beds repeated again and again. That these inclined anticlinal and synclinal axes are not purely hypothetical will, I think, appear when we consider that if we were to measure the distance from the Ditsham limestone to where the dip becomes reversed between Stokenham and Friscomb, we should find it amount to rather more than seven miles, which, at an angle of 35° only, would give a thickness of up-

wards of 20,000 feet for the relatively small portion of the South-Devon series which overlies the Torbay limestones,—an estimate which would be beyond all probability.

This higher group of rocks is only very sparingly fossiliferous. A few fossils are stated to have been found in the cliffs of Plymouth Sound; and Encrinites occur in the calcareous seams at Kingswear. Mr. Pengelly has seen traces of them in Scabbacombe Bay and at Beeson Cellers, near Torr Cross; but these remains are in such a wretched condition that, with the exception of *Petraia Celtica*, Lonsd., I am not aware that any of them have been determined.

IV. METAMORPHIC ROCKS OF THE SALCOMBE DISTRICT.

These rocks consist chiefly of mica-slate and of a mixture of granular quartz with a mineral allied to chlorite, and have been fully described by the late Sir Henry de la Beche in his ' Report of the Geology of Devon and Cornwall '*, and by the authors of the ' Devonian System,' in the memoir already quoted †, to which reference must be made for mineral details. As observed by the latter authors, mica-slate prevails most towards the south, and the chloritic rocks towards the north; but the different varieties are so commingled that they cannot be separated into two formations‡. Although greatly undulated and contorted, they have a general dip towards the argillaceous-slate system on the north, which has likewise a northern dip; but the actual contact is nowhere seen, and the manner in which the altered and unaltered rocks are brought into apposition is somewhat obscure. The argillaceous rocks are high up in the Devonian system; nevertheless no clear evidence of a line of fault between them and the metamorphic rocks has been observed. Assuming that the latter belong to some earlier epoch, it is possible, perhaps, that they may have been thrust up from below, breaking through all the lower beds of the Devonian series, while they carried up and threw off to the northward the higher beds of the Kingsbridge district. Such an hypothesis is quite consistent with what we know of the general relations of the slaty rocks of South Devon, and may assist in explaining the relative positions of the beds, as the metamorphic rocks might then have formed a counterforce to that which brought up the granite of Dartmoor, and have contributed to the production of those long narrow anticlinal and synclinal folds into which the intervening slaty rocks have been thrown. At the same time, it must be observed, these altered rocks of Start Point and the Bolt have not a very ancient aspect, and the dark-blue slates of Hopes Cove exhibit that minute crumpling and abundant intersection with veins of red and white quartz so frequently observed in slate rocks at the point of commencing metamorphism. Moreover the rocks appear on the whole to be more highly crystalline, and the effects of metamorphic action seem to increase progressively, as we proceed towards the south; and it appears to me more probable that these micaceous and chloritic rocks are altered depositions of Devonian age, mantling over a granitic mass,

* P. 27.   † Pp. 658 and 661.   ‡ *L. c.* p. 659.

like that of Dartmoor, more deeply seated.   The dynamical effects on the slate rocks which occupy the interval between Salcombe and the Dartmoor granite at South Brent and Ivy Bridge would still be much the same, as there is pretty good evidence to show that all these great granitic masses of Devon and Cornwall belong to one epoch [*], and have been the direct cause which has brought the slaty rocks into their present position.

V. Granite of Dartmoor and of Brown Willy (Camelford).

The Dartmoor granite has been also fully described by Sir Henry De la Beche [†], Sir Roderick Murchison and Prof. Sedgwick [‡], Mr. Godwin-Austen [§], and other writers of earlier date.   It will be sufficient, therefore, for my present purpose merely to restate the relations these masses bear to the surrounding rocks, in order that their influence in bringing about the general disposition of the latter, above described, may not be overlooked.

The Dartmoor granite has pressed the Culm-measures to the northward, bringing the beds into nearly vertical positions.   On the east, between Dunsford and Bovey Tracey, it has broken through the beds, which range up to it more or less at right angles to its margin; and the volcanic rocks interstratified with them are altered and rendered crystalline.   South of Bovey Tracey, however, and thence to Skeriton, the granite throws the Culm-measures off to the southeast.   At its southern extremity, near Ivy Bridge, it has broken through the Devonian rocks; but around Cornwood the latter form a shallow basin between the granite at Harford and the offstanding protruding mass of Crown Hill Down.   Westward of Crown Hill Down, and, in fact, along the whole south-western border of Dartmoor, as far as Meavy, the granite has broken through the bedding, which trends up to its edge; but thence northwards, almost to Bridestow, the beds dip away from the granite at for the most part low angles, and occasionally they are nearly horizontal, as in the neighbourhood of Petertavy.

The granite of the Camelford Hills throws off the beds to the south, which dip at moderate angles towards Liskeard.   On the north it has carried the beds which range up from the north of Hingston Down to the north-east, and beds on the same geological horizon dip off the granite on the west at tolerably high angles.   Lower beds, however, are brought up on the east and north-west of the granite.   Those on the east dip away from its margin somewhat irregularly; those on the north-west stretch away towards Cadon Barrow, throwing off higher beds to the north-east and west.

The rocks contiguous to the granite are altered by it; and the resulting metamorphic rock, of course, varies with the original constitution of the rock acted upon.   Generally the effects are very feeble at a distance of a quarter of a mile from its margin; but it extends further where the beds dip off from the granite than where they

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[*] See also on this point Sedgwick and Murchison, *l. c.* p. 685, and De la Beche, Rep. p. 165.

[†] Rep. p. 157 *et seq.*   [‡] *L. c.* p. 685.   [§] *L. c.* p. 476.

trend up to it, for obvious reasons; and it varies also with the relative fusibility of the rock, the volcanic rocks being the first to exhibit any alteration, which they do by becoming crystalline and altered in the arrangement of their elements, as near Petertavy and on the east of Dartmoor.   Among the Culm-measures the resultant metamorphic rock is commonly either a minutely crystallized black schorl-rock of uniform texture, or a mixture of this with semivitrified grit in alternating layers, or a uniform mixture of small schorl-crystals and quartz-grains.   Some of the rocks, however, are rendered micaceous; and among the older rocks this result is the more common effect; but occasionally crystals of chiastolite, more or less perfectly developed, appear in the slates, as on the north of Ivy Bridge.   None of these altered rocks, however, exhibit a high degree of metamorphism, but the contrary; and we pass abruptly from these slightly altered rocks to highly crystallized coarse-grained granite, without any intervening rocks which would indicate a gradation from the unaltered Carbonaceous and Devonian rocks into the granite.   The truly igneous character of these granitic masses is therefore as clearly shown as any geological phenomenon can be; and around the margin of the moor the granite has thrown out veins, both large and small, into the adjacent rocks.   Whether the elvans, which at Blisland and St. Neots also appear to have emanated from the molten mass, really did so or not, we need not stop to inquire.

VI. General Remarks.

It follows from what has been stated that neither the highest nor the lowest portion of the Devonian system, as seen in North Devon, occurs on the south side of the Culm-measures, and that the slate rocks which pass under the Carbonaceous series on the north are not the same as those that rise from beneath them on the south.   There is, no doubt, a good deal of similarity between them, as there is between much of the slaty rocks of Devonshire; and this, together with the fact that both are locally fossiliferous and contain some organic remains in common, has led to the inference that the opposite sides of the trough are symmetrical.   So far as the Culm-measures are concerned, this appears to be the case; and although the local admixture of volcanic material may have somewhat augmented the thickness of these beds in the south, the small patches of limestone at a certain distance from the base of the series, both in the north and in the south, appear to indicate a well-marked horizon on which there existed a change of conditions; and hence the subdivision of the Carbonaceous system by Sedgwick and Murchison into a lower and an upper series is a natural one[*].   But in the south there is complete unconformability between the base of the Culm-measures and the underlying Devonian rocks.   If we follow the southern range of Culm-measure limestones from Launceston eastward, round the margin of the Dartmoor granite, by Bridestow to Drewsteignton, and thence to the north of Dunsford, we find that the interbedded volcanic rocks between Dunsford and Chudleigh correspond in their relative position,

[*] L. c. p. 670.

as regards both the range of limestones and the base of the measures, with the similar volcanic rocks of the Brent Tor district.   There is more grit, perhaps, on the east side of the Dartmoor granite than on the west, though even this may be questioned; but in the abundance of chert-beds, and in their general petrological aspect, they are precisely similar.   Now the base of these lower Culm-measures does not everywhere rest on the same part of the underlying Devonian rocks.   The beds which underlie them at Penter's Cross and Whitechurch Down are considerably lower than those on which they rest at Petherwin and Trewen; while on the east they lie directly on the denuded surfaces of the Torbay limestones, which are probably more than two thousand feet higher in the series; and if the Culm-measures of the Ilsington and Holne district are not, as I believe, brought into contact with the older rocks by faults, then they rest on successively lower and lower beds as we pass from Bickington to Skeriton, near Dean Church.   Nor has this want of conformability altogether escaped observation; for it is noticed by Prof. Sedgwick as occurring "near Launceston"[*], and by Godwin-Austen in the Newton Bushell district[†].   As already stated, on the west of Dartmoor the great undulations into which the upthrust of the granite has thrown the beds has affected both systems; but nevertheless the minor contortions and crumplings of the higher series have no relationship to those of the lower, and, moreover, the angles at which the beds of the two formations rest are commonly altogether different.   Now this unconformability on the southern side of the Culm trough is so considerable that it throws doubt upon the reality of the apparent regular succession on the north, and leads to the suspicion that the conformability which is there supposed to exist may be more apparent than real.   The late Mr. Thomas Weaver did not, in fact, consider the Culm-measures to rest conformably on the underlying rocks; for he says, " The Wavellite schists and sandstone (7), and culmiferous shales (8), though apparently in some places in parallel (conformable) position with the Trilobite slates [‡] (6), do, when thoroughly examined upon the line of outcrop in the district, form a break with No. 6, and are unconformable thereto"[§]. That there is some difficulty in detecting any want of conformability is due to the similarity in appearance of the slaty rocks of the two series and the absence of those interstratified beds of volcanic ash which are so serviceable in enabling us to follow the lines of strike in the south.   But if, as I believe, the Culm-measures have been laid down on the denuded surface of the older rocks, then there is a break in the sequence and a lapse of time to be accounted for.

It is obvious that the true position of the Plymouth and Torbay limestones in the general mass of the South-Devon rocks is a matter of great importance to the correct interpretation of the structure of the country.   Looking at the map, the question might suggest itself whether or not the limestones which range by Bickington and Ashburton to Dean Prior might not be the same as those of Ogwell, Ipplepen, and Dartington, thrown over a broad anticlinal axis of the

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[*] Proc. Geol. Soc. vol. ii. p. 681.   [†] *L.c.* p. 458.   [‡] *I. e.* the Pilton group.
[§] " Geological Relations of North Devon," Proc. Geol. Soc. vol. ii. p. 589.

lower slates to the north-west. This view, no doubt, would have the merit of simplifying the structure of the country south of the Culm-measures, inasmuch as it would bring the limestones of South Petherwin, Padstow, the Looe river, and St. Germans into relation with those of Plymouth and Torbay on one horizon; and, as will be shown hereafter, although the distribution of organic life in these rocks is very irregular and often local, nevertheless palæontological records would not altogether discountenance it. But however plausible this interpretation may appear at first sight, all the direct evidence obtainable, as already stated, is entirely against it; and whether we cross the country from Bickington by Hobbin Wood to Chircombe Bridge, or from Ashburton by Woodland to Torbryan, or, further to the south, from the granite by South Brent to Black Hall, near North Hewish, we appear to have a clear upward succession of the beds; and in the two or three instances in which the volcanic rocks were observed to have exerted any influence on the contiguous slates, it was on the Ashburton side only [*].

There is equal difficulty in regarding the Plymouth limestone as the same as those of Milladon and the Looe river, brought up to the surface by an anticlinal axis with the intervening beds troughed in between them, notwithstanding the apparently horizontal thinning-out of the limestone at each extremity, and the contortion seen at St. John's. This view would, of course, require the beds contained in the synclinal trough west of the Looe river, as they trended up to the Lyhner and the Hamoaze, to become inverted, and in this position to range eastward to the granite north of Ivy Bridge, where, partly by the granite and partly by faults, the continuity of the belt of rocks became destroyed. But we cannot assume this view without doing violence to the apparent relations of the bedding on either side of the mouth of the Seaton river; and there is, in fact, no direct evidence to bear it out. Moreover it would bring these beds into relationship with the rocks which certainly overlie the limestones of Plymouth and Brixham on the south, and occupy the whole of the Dartmouth and Kingsbridge district, with which, notwithstanding a considerable resemblance in lithological character, there is no palæontological evidence to connect them; whereas the rocks which are seen beneath the limestones at Mudstone Bay and Meadfoot Sands are related to them by similarity of fossil contents, and more especially by their fish-remains. On the other hand, the slates which occupy the country between the Ogwell and Ashburton limestones resemble, both petrologically and in the abundant association of volcanic rocks, the beds which, brought down from the Liskeard district by St. Germans and Saltash, and from the coast by Polbathick and by Anthony, are continued by Plympton to the southern extremity of the granite at Ivy Bridge.

But a directly opposite interpretation has also been suggested respecting the stratigraphical relations of these beds, viz. that the

* In this I am borne out by Mr. Godwin-Austen, who regards the limestones of Ashburton and St. Germans as a lower range. (Trans. Geol. Soc. vol. vi. p. 462; also Sedgwick and Murchison, *l. c.* p. 653.)

red rocks of Staddon Point, Morleigh Down, and the Dart river have been brought up from below the Plymouth limestone by an inverted anticlinal axis; and I believe Mr. Beete Jukes is inclined to favour this view. There appears to be, however, on the east shore of Plymouth Sound, south of Mount Batten, and from the limestone of Brixham, along the river Dart, and the coast at Mann Sands, an upwards series, through grey, blue, and purple slate, to the red grit, which rocks succeed each other conformably; and the limestone of Berry Pomeroy and Marldon are overlain by variegated argillaceous slates, surmounted at Blagdon Cross by red grits like those of Staddon Point and the banks of the Dart. No similar rocks, however, are seen rising up from below the limestone among the lower rocks north-west of Dartington and Ogwell; nor are any such again brought up to the surface from beneath the limestone in the long downward succession of the beds between Plymouth and the Harrowbridge station, on the Tavistock railway.

The fossiliferous rocks of South Petherwin appear to be commonly held among geologists to be Upper Devonian, and are placed by Mr. Salter on the horizon of the red slates of Morte Bay *. Looking, however, to the relations of the beds which surround the granite of the Camelford Hills, and following, as I have done, the volcanic rocks of Alternan and Lewannick, which support the Petherwin limestones, round to the westward by St. Clether, Davidstow, and Tintagell, to Delabole and St. Mabyn on the one hand, and by Stoke Climsland, South Hill, Callington, and New Bridge, to St. Cleer and the vicinity of Liskeard on the other, there seems to be no reasonable doubt that we are following the same range of beds, and that the granite, in breaking through and carrying up the Devonian rocks, has done so without producing so great an amount of disturbance as to destroy the general relations of the surrounding rocks, although some lower beds are brought up on the south-east and north-west of the granitic mass, and carry these volcanic rocks further from its margin. There appears, therefore, to be evidence, as clear as we can expect to find among rocks of this kind, that the igneous rocks which are seen to dip away from the granite on all sides except that towards Bodmin, all belong to a single group; and that the band of volcanic rocks at Alternan, on the north, holds the same relative position as regards the granite that the smaller, but similar, band at St. Cleer does on the south— in other words, that the igneous rocks of Alternan and St. Cleer, and the more horizontal masses further to the east at South Hill and Callington, are on the same, or nearly the same, geological horizon. Now we have a tolerably clear upward succession from the beds which are thrown over to the north of the Hingston Down granite, and which range up to Alternan, across the strike to the limestones of South Petherwin—and an equally clear downward series from Whitechurch Down, along the Tavistock railway, to Plymouth. If, therefore, the Petherwin limestones were really

* "Upper Old Red Sandstone and Upper Devonian Rocks," Quart. Journ. Geol. Soc. vol. xix. p. 484, 1863.

above the Plymouth and Torbay range, where is the place of the latter and of the red grits which overlie them at Staddon Point and Blagdon Cross, on the north of Hingston Down ? There can be no question about the rocks of Hingston Down and the vicinity of Buckland Monachorum being the lowest in the line of country between South Petherwin and the coast at Whitesand Bay ; and admitting that the rocks of the St. Breock's anticlinal axis are, as I believe, somewhat lower in the series, we still find no trace of the red rocks of Staddon Point and the Kingsbridge district, between them and the volcanic beds of St. Clether and Tintagell, as they curve round by Delabole to the coast at Pentire and Padstow ; and although it is possible that they may have thinned out before reaching Bodmin, that could hardly be the case as regards the country north of Plymouth. There really appears, therefore, to be so little ambiguity about the stratigraphical relations of these different beds, that it becomes necessary to examine the evidence afforded by organic remains which has led to a different opinion.

The following Table (Table II.) gives the distribution of the 76 species from the fossiliferous rocks of South Petherwin. The list of species is extracted from Table II. of Mr. Etheridge's elaborate memoir in the 23rd volume of the Society's Journal *. The columns headed " Europe " and " Carboniferous " are likewise extracted from Mr. Etheridge's lists. These Tables have been used also in compiling the other three columns, there being only two species in column 5 which are not contained in his Tables ; and they are introduced on the authority of Prof. Phillips and Mr. Davidson. For the rest I am indebted to the writings of Prof. Phillips and Messrs. Godwin-Austen, Salter, and Davidson, and to some unpublished information derived from the last two authorities through Mr. Pengelly. The 6th column includes all the localities named in Table I. (p. 432), together with those of Walton, Rowdown, near Washburton, and Yealmpton Creek ; but the list is very incomplete. The 7th column is likewise very incomplete, but comprehends the calcareous and fossiliferous rocks which range by Ashburton and Newnham Park to St. Germans and the Looe river, and thence on towards the Fowey. It may be observed, however, that some of the Petherwin fossils, collected many years ago, before the limits of the Culm-measures were clearly defined, may not really belong to the underlying rocks. This is the case with *Loxonema tumidum*, *Poterioceras fusiforme*, and perhaps *Murchisonia angulata*, as none of these species, except the last, are known to occur elsewhere in Devonian rocks†.

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* P. 616 *et seq.* Three species have been omitted, as *Orthoceras ibex*, Phill., is the same as *O. Phillipsii*, D'Orb., and *Athyris indentata*, Sow., is the *A. concentrica*, V. Buch (*vide* Sow. in Trans. Geol. Soc. 2nd ser. vol. v. p. 784); *A. decussata*, Sow., is likewise a synonym of *A. concentrica*, according to M'Coy and De Koninck. (See Davidson, Mon. Palæont. Soc.: Brachiopoda, vol. iii. Part 6. No. 1. p. 17 ; consult also Phill. Pal. Foss. p. 70, and Morris, Cat. Brit. Foss. p. 130).

† The lowermost beds of the Carbonaceous rocks on the south side of the Culm trough are locally fossiliferous. They contain Goniatites, Orthoceratites, and some other fossils, and, near Landlake and Chudleigh, *Posidonomyæ*. The fossils named above, as also *Orthoceras striatum*, *Sanguinolaria elliptica*, &c., may have come from these lower beds.

TABLE II.

Species.	Peculiar to Petherwin *	North Devon — Upper	Middle	Lower	Middle and South Devon — Upper limestones	Slates. Meadfoot, &c.	Lower limestone range	Europe — Upper	Middle	Lower	In any area — Upper	Middle	Lower	Carboniferous
Petraia Celtica, *Lonsd*...............	...	*	...	...	*	*	*	...	...	...	*	*		
Hallia Pengellyi, *M.-Edw.* ‡	...	..	...	...	*			...	...	...		*		
Amplexus tortuosus, *Phill.*	...	...	*	...	*	...	*?	...	*	...	...	*		
Cyathophyllum cæspitosum, *Goldf.*	...	...	*	...	*	...	...	...	*	...	...	*		
Cyathocrinus ellipticus, *Phill.*	*													
—— variabilis, *Phill.*	...	*	*	...	...	...	...				*	*	...	*
Phacops laciniatus, *Ræm.*	...	...	...	..	*	...	*	*	*	...	*	*		
—— latifrons, *Bronn*	...	*	...	?	*	*	*	*	*	*	*	*		
—— granulatus, *Münst.*	...	*	...	...	*	*	...	...	*	...	*	*		
Entomos serrato-striata, *Sandb.*	†	...	...	...	...	...	...	*	*	...	*	*		
Fenestella antiqua, *Goldf.*	...	*	*	*	*	*	*	...	*	...	*	*	*	*
Polypora laxa, *Phill.*	...	*	...	...	*	...	...	...	*	...	*	*	...	*
Athyris concentrica, *V. Buch*	...	*	*	...	*	*	*	*	*	...	*	*		
Spirifera Verneuillii, *Murch.*	...	*	*	...	*	...	*³	*	*	...	*	*		
—— Urii, *Flem.*	...	*	...	...	*	...	...	...	...	...	...	*	..	*
—— lineata, *Mart.*	...	*	...	...	*	...	...	*	...	...	*	*		
Atrypa desquamata, *Sow.*	...	?	*	...	*	...	*	...	*	...	...	*		
—— reticularis, et var. aspera	...	...	*	...	*	...	*	*	*	*	*	*	*	
Rhynchonella pleurodon, *Phill.*	...	*	*	...	*	*	...	...	...	...	*	*	...	*
—— pugnus, *Mart.*	...	*	*	...	*	...	...	*	*	...	*	*	...	*
—— reniformis, *Sby.*	...	*	...	...	*	...	...	...	...	...	*	*	...	*
Camarophoria rhomboidea, *Phill.* ...	...	...	...	...	*	...	*	...	*	...	...	*		
Orthis striatula, *Schloth.*	...	*	*	...	*	...	...	*	*	...	*	*		
—— interlineata, *Sow.*	...	*	*	*¹	...	...	...	...	...	...	*	*		
Streptorhynchus crenistria, *Phill.* ...	...	*	*	...	*	*	*²	*	...	...	*	*	...	*
Strophalosia productoides, *Murch.* ...	...	*	...	...	*	...	...	*	...	...	*	*		
Productus subaculeatus, *Murch.*	...	...	...	...	*	...	...	*	*	...	*	*		
Sanguinolaria sulcata, *Münst.*	...	*?	...	...	*	...	*	...	...	...	*	*		
Ctenodonta elliptica, *Phill.*	*													
Orthonota semisulcata, *Phill.*non *Sow.*	*													
Modiola amygdalina, *Phill.*	*													
Schizodus deltoideus, *Phill.*.............	...	...	*	...	...	...	...	...	...	...	...	*		
Aviculopecten granulosus, *Phill.* ...	*													
—— transversus, *Sow.*...............	...	*	...	...	...	...	...	*	*	...	*	*	...	*
—— alternatus, *Phill.*	*													
—— granosus, *Sow.*......................	*													
—— arachnoideus, *Phill.*...............	*													
Avicula subradiata, *Phill.*	...	*	...	...	*	...	...	...	...	...	*	*		
—— exarata, *Phill.*	*													
Pterinea ventricosa, *Goldf.*	†	...	...	...	...	...	...	...	...	*	...	...	*	
—— spinosa, *Phill.*	...	...	...	*	...	...	*	...	...	...	...	*	*	
Cardiola retrostriata, *Keys.*.............	†	...	...	...	...	...	...	*						
Euomphalus serpens, *Phill.*	...	*	*	...	*	*	...	..	...	...	*	*		
Natica nixicosta, *Phill.*...............	†	...	...	...	*	...	...	*	...	...	*	*		
Pleurotomaria cancellata, *Phill.*	...	*?	...	...	*	...	?	...	...	...	*	*		
—— aspera, *Sow.*......................	...	*?	...	*	*	...	...	...	...	...	*	*	*	
—— antitorquata, *Phill.*	...	...	...	...	*	...	...	*	*	...	*	*		

TABLE II. (continued).

Species.	Peculiar to Petherwin *.	North Devon			Middle South Devon			Europe			In any area			Carboniferous.
		Upper.	Middle.	Lower.	Upper limestones.	Slates, Meadfoot, &c.	Lower limestone range.	Upper.	Middle.	Lower.	Upper.	Middle.	Lower.	
Loxonema nexilis, *Phill.*	...	...	...	...	*	...	...	...	*	...	...	*		
—— sinuosa, *Phill.*	*													
—— tumida, *Phill.*?	†	...	...	...	...	...	...	.	...	...	...	...	...	*
Murchisonia angulata, *Phill.*?	...	*	...	...	...	...	...	*	...	...	*	...	...	*
Bellerophon bisulcatus, *Röm.*	...	*	*	...	...	*	*	...	.	...	*	*		
Orthoceras cinctum, *Sow.*	...	?	...	...	*	...	...	...	...	...	...	*	...	*
—— laterale (O. undulatum)	...	...	...	...	*	...	...	...	...	...	...	*		
—— striatum, *M'Coy*?	...	*	...	...	...	...	...	...	.	...	*	...		*
—— Ludense, *Phill.*	...	...	...	?	*	...	...	...	.	...	...	*	?	
—— striatulum, *Sow.*	*													
—— Phillipsii, *D'Orb.* (O. Ibex, *Phill.*)	†	...	...	...	...	...	...	...	*	...	...	*		
Poterioceras fusiforme, *Sow.*?	†	...	...	...	...	...	...	...	...	...	...	...	...	*
Cyrtoceras rusticum, *Phill.*	...	...	...	...	*	...	...	...	...	...	...	*		
Goniatites biferus, *Phill.*	†	...	...	...	...	...	...	...	*	...	...	*		
—— vinctus, *Sow.* (G. insignis, *Phill.*)	...	*	...	...	...	...	...	...	...	...	*			
—— linearis, *Münst.*	†	...	...	...	...	...	...	...	*	...	...	*		
—— subsulcatus, *Bronn*	*													
Nautilus megasipho, *Phill.*	*													
Clymenia lævigata, *Münst.*	...	...	...	...	*	...	...	...	*	...	...	*		
—— striata, *Münst.*	†	...	...	...	...	...	...	...	*	...	...	*		
—— linearis, *Münst.* (C. undulata, *Phill.*)	...	...	...	...	*	...	...	*	?	...	*	*		
—— bisulcata, *Münst.*	*													
—— fasciata, *Phill.*	*													
—— sagittalis, *Phill.*	*													
—— plurisepta, *Phill.*	*													
—— valida, *Phill.*	*													
—— Münsteri, *M'Coy*	*													
—— Pattisoni, *M'Coy*	*													
—— quadrifera, *M'Coy*	*													
Total 76	21* 10†													
	31	27	16	4	37	9	14	18	24	3	33	48	6	14

* The asterisk in this column indicates that the species is peculiar to South Petherwin. Those species marked thus †, although not peculiar to South Petherwin, are not found elsewhere in British Devonian rocks.

‡ Coll. Geol. Soc. et Edw. & Haime, Monograph Pal. Soc. p. 223.

[1] Phillips, Pal. Foss. [2] Davidson, in Col. Pengelly. [3] Murchison, Siluria, p. 395.

If from the 76 species recorded in the above Table we deduct 21 species as being peculiar to the locality, *i. e.* not found elsewhere in Britain or the continent of Europe, and 10 others that are not found elsewhere in British Devonian rocks, making 31 in all, we have only 45 species left for comparison with other British localities.

Now, of these 45 species, 27 are said to occur in the upper group of
North Devon; but, on the other hand, there are in the Upper North-
Devon group 78 species which do not occur in the Petherwin beds.
But there are 37 species in common between Petherwin and the
Torbay or South-Devon limestones; and if to these we add 3 addi-
tional species from the Middle North-Devon or Ilfracombe group,
this will make 40 species, and two others from the beds which
underlie the Torbay limestones will give a total of 42 species out
of 45 as common to the Middle Devonian and the Petherwin rocks,
against 27 in common between Petherwin and the Upper North-
Devon group.   This leaves but 3 species that are not found in the
Middle Devonian rocks of Devonshire, exclusive of the 31 that are
peculiar, viz. *Avicula transversa*, *Murchisonia angulata*, and *Ortho-
ceras striatum* *, which are Upper-Devonian and Carboniferous species.
The affinity, therefore, of the Petherwin fauna with that of the
Upper North-Devon group is not so strong as it is with that of the
Middle group of South Devon.

If we compare the Petherwin fauna with those of the Upper and
Middle groups of the European continent, the results are nearly the
same.   Deducting from the 76 Petherwin species the 21 not found
elsewhere, we have 55 species remaining, of which 18 occur in Con-
tinental Upper, and 24 in Continental Middle Devonian rocks.   And
if we compare the same 55 species with the fauna of the Upper and
Middle groups of all areas collectively, we have 33 for the Upper
and 48 for the Middle group in common.   Of these, 3 species are
met with common to Petherwin and the Upper Devonian group that
do not occur in the Middle group, against 18 species common to
the latter and Petherwin that do not occur in the Upper group, but
of which two species, viz. *Poterioceras fusiforme* and *Loxonema
tumida*, occur also in Carboniferous rocks, and, possibly, do not
really belong to the Petherwin lower fauna †.

To pass to particular species, it may be observed that some im-
portance has been attributed to the occurrence of *Cypridina* (*En-
tomos*) *serrato-striata*, Sand., in the Petherwin rocks, as it was for-
merly supposed to be a characteristic fossil of the Upper division
of the Devonian system; but it is now known to occur likewise in
the Middle division.   The *Clymeniæ*, again, have been appealed to
as evidence of the Upper-Devonian character of the Petherwin
beds; but of the 11 species that have been met with in that locality,
8, according to Mr. Etheridge's lists, appear to be unknown else-
where, and therefore tell us nothing.   Of the 3 remaining species
2 are true Middle-Devonian forms, and the other is a Middle-
Devonian species in South Devon (and on the Continent?), and an
Upper-Devonian form in France.   On the other hand, the genus
Cyrtoceras is not known in true Upper Devonian rocks, nevertheless

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* This last is not contained in Prof. Phillips's lists.
† In a paper " On the Geological and Chronological Distribution of the De-
vonian Fossils of Devon and Cornwall," published in the ' Geologist' for 1862,
Mr. Pengelly arrived at the conclusion that the Petherwin beds were " somewhat
more ancient than those of Barnstaple."

it occurs in the Petherwin beds; and, lastly, there are 6 Brachio-
pods named by Mr. Etheridge * as being characteristic of the North-
Devon Upper Devonian rocks, and not occurring below them, viz.
*Athyris oblonga, Discina nitida, Lingula squamiformis, Productus
scabriculus, Terebratula sacculus* and *Rhynchonella acuminata* †, none
of which are known in the Petherwin beds.

These results, so far as they go, are, I believe, in accordance
with those of Mr. Salter‡, who, reasoning from the mixed cha-
racter of the Petherwin fauna, consisting partly of Upper- and partly
of Middle-Devonian forms, assigned to these beds a middle position
between the fossiliferous zones of the two upper divisions of the
Devonian system, or, at any rate, a place below the Marwood beds;
and he gave, among other reasons for doing so, the presence of *Cly-
menia* and *Cardiola rostrata*. This method of reasoning, however,
can hold good only so long as there is no evidence of stratigraphi-
cal superposition. That *Cardiola rostrata* lived in Upper-Devonian
times on the Continent is no evidence that it did not exist in Middle-
Devonian times in Britain; and perhaps a rigid comparison of the
Devonian fauna of North America and elsewhere with that of
Devonshire and continental Europe might throw some additional
light on our knowledge respecting the migration of species, and
their distribution in time and space.

The beds brought up by the narrow anticlinal axis at Yealm
Bridge may perhaps be rather higher in the series than the Pether-
win rocks; but of this there is no evidence. The fossils are *Phacops
latifrons, Entomos?* (*Cypridina*) *serrato-striata* §, and *Petraia Cel-
tica*, which are likewise Petherwin fossils, with *Sanguinolaria ellip-
tica*, Phill., and *Bellerophon hiulcus*, Sow.; but these latter, as we are
told by Mr. Pattison ‖, were found in the loose upper layers; and
it is not quite clear whether or not they may belong to the Upper
or Carbonaceous system.

In endeavouring to determine the position of the fossiliferous
rocks of Liskeard and the Looe-river district by means of their
organic remains, we are embarrassed by the want of evidence; for
although vast numbers of casts of fossils have been observed, they
are mostly in such a wretched condition that only a few of them
have been identified specifically. Besides the forms enumerated
in the following Table (Table III.), species of *Orthoceras*, of Brachio-
poda, and of Cœlenterata have been noticed in the neighbourhood
of Liskeard; and it was from within this area that Mr. Pengelly
obtained the *Phacops punctatus* figured in Mr. Salter's monograph¶.
In the Looe-river district, including Poluran, Fowey, &c., and the
shores of Whitesand Bay, other species, not included in the Table,
have been found, of the genera *Aviculopecten, Avicula, Ctenodonta,*

* *L. c.* p. 668.
† *L. c.* p. 668. A seventh is given in the text, viz. *Spirifera Urii*; but this
species occurs at Barton, and is recorded as a Middle-Devonian species in
Tables 2 & 9 of the Memoir.   ‡ Quart. Journ. Geol. Soc. vol. xix. p. 483.
§ On the authority of Mr. S. R. Pattison.
‖ Trans. Royal Geol. Soc. of Cornwall, 35th Ann. Rep. p. 64.
¶ Palæont. Soc. Mon. Trilobites, pt. 1. pl. i. figs. 17–19.

Orthoceras, and *Goniatites,* with some Trilobites not fully identified, and many species of Cœlenterata*. But as far as the known species at present go, they do not bear out the view generally prevalent among geologists, that these Looe-river beds are the representatives in time of the Lower Devonian or Linton group of North Devon; and the fine Ichthyodorulites from this locality, in the collection of Mr. Pengelly, have the oblique ridges appertaining to the Carboniferous type†.

The 42 species from the Looe district entered in Table III. do

TABLE III.

Fossils of the Looe-River, Liskeard, and Padstow districts compared with those of Petherwin, and with the Upper, Middle, and Lower Devonian Groups of Britain and Continental Europe respectively.

Species.	Localities.									
					British.			Europe.		
	Looe-River District.	Liskeard.	Padstow.	Petherwin.	Upper.	Middle.	Lower.	Upper.	Middle.	Lower.
Caunopora ramosa, *Brass.*	*†	...	...	...	...	*				
Petraia Celtica, *Londs.*	*	*	*	*	*	*				
—— pluriradialis, *Phill.*	*	...	...	...	*	*†	*	...	...	*
Favosites dubia, *Blainv.*	*¹	...	...	...	...	*	...	...	*	
—— fibrosa, *Goldf.?*	*†	...	...	...	...	*	...	...	*	
Heliolites porosa, *Goldf.*	*	...	...	...	...	*	...	...	*	
Pleurodictyum problematicum, *Goldf.*	*	*	...	..	...	*	...	*	*	*
Cyathocrinus megastylus, *Phill.*	*²	...	...	...	...	*				
Phacops laciniatus, *Röm.*	*	*³	*	*	...	*	...	...	*	*
—— punctatus, *Stein.*	...	*¹	...	...	...	*	...	...	*	
—— latifrons, *Bronn*	...	*	*	*	*	*	...	*	*	*
Fenestella antiqua, *Goldf.*	*	*	...	*	*	*	*			
Athyris concentrica, *V. Buch*	...	...	*⁵	*	*	*	...	*	*	
Atrypa desquamata, *Sow.*	*	*								
—— reticularis, et var. aspera, *Schloth.*	*	...	...	*	...	*	...	*	*	
Chonetes Hardrensis, *Phill.*	*	...	...	...	...	*	...	?	?	
Leptæna laticosta, *Conrad*	*	...	...	...	...	*‡	...	...	*	*
Orthis arcuata, *Phill.*	*	...	...	...	...	*	*			
—— resupinata, *Phill.*	*⁹	...	...	*	*	*	...	*	*	
—— hipparionyx, *Vanux.*	*	...	...	...	...	?				
Rhynchonella Pengelliana, *Dav.*	*									
Spirifera primæva, *Stein.*	*	...	...	...	...	...	...	...	*	*
—— curvata, *Schloth.*	*⁵	...	...	...	...	*	...	...	*	
—— hysterica, *Schloth.*	*	...	*	...	...	?	*	*	*	*
—— lævicosta, *Valen.*	*	...	...	...	...	*	*	*	*	
—— speciosa, *Schloth.*	*	...	*	...	...	*	...	...	*	*
Spiriferina cristata, *Schloth.*	*	...	...	...	*	*				
Pentamerus brevirostris, *Phill.*	...	...	*⁹	...	...	*	...	...	*	
Stringocephalus giganteus, *Sow.*	...	...	*⁹	...	...	*	...	...	*	

* The corals enumerated by Mr. Couch, Trans. Roy. Geol. Soc. of Cornwall, 33rd Ann. Rep., are not included, as their specific determinations were made many years ago, before the genera and species had received their modern definitions.

† The *Pteraspides* and *Cephalaspides* of Padstow and the Looe-river district are not specifically the same as those of the Lower Old Red.

TABLE III. (*continued*).

Species.	Looe River District.	Liskeard.	Padstow.	Petherwin.	British. Upper.	Middle.	Lower.	Europe. Upper.	Middle.	Lower.
Streptorhynchus gigas, *M·Coy*	*									
—— crenistria, *Phill.*	*	...	...*	*	*	*	...	*		
—— persarmentosa, *M·Coy*	*									
—— umbraculum, *Schloth.*..................	*?	...	*	...	...	*	*	...	*[10]	
Strophomena rhomboidea, var. analoga, *Phill.*	*[9]	...	...	...	...	*				
Pterinea spinosa, *Phill.*	*	...	...	*	...	...	*			
Loxonema lincta, *Phill.*	*[6]	...	...	...	...	*				
Bellerophon bisulcatus, *Röm.*	*	*	...	*	...	*‡				
Pleurotomaria cancellata. *Phill.*	*[7]	...	...	*	*					
Orthoceras Ludense, *Phill.* non *Sow.*	...	...*	*[5]	*	*	*				
Serpula, n. sp.	*[9]									
Pteraspis (Scaphaspis) Cornubicus, *M·Coy* ..	*	...	*	...	...	*||				
Cephalaspis ? Carteri, *M·Coy*	*									
And remains of several other species of fish.										

[1] De la Beche, Mem. Geol. Surv. vol. i. p. 101. [2] Phill. Pal. Fos. p. 32. [3] Pengelly in Davidson's Monograph, Palæont. Soc. [4] Salter in Col. Pengelly. [5] Etheridge, *l. c.* table ii. p. 621. [6] Murchison, Trans. Roy. Geol. Soc. of Cornwall, 33rd Ann. Rep. [7] Couch on Foss. of Cornwall, Trans. Roy. Geol. Soc, of Cornwall, 33rd Ann. Rep. [8] Pattison, Trans. Roy. Geol. Soc. of Cornwall, 35th Ann. Rep. [9] Coll. Mus. Pract. Geol. [10] Siluria, 4th Edit. p. 399. † and at Ashburton. ‡ Meadfoot. || Mudstone Bay.

not, as already stated, include all the forms; and of these 42 species, 5 have not been meet with elsewhere, leaving therefore 37 species for comparison, all of which, with the exception of two, viz. *Orthis hipparionyx* and *Pterinea spinosa* are known to occur in Middle Devonian rocks, either of Britain or Europe, and all, with the exception of the above, and *Spirifera primæva*, and perhaps *Spirifera hysterica* (the occurrence of this latter species in South Devon being not quite certain), are met with in British Middle Devonian rocks. On the other hand, only 8 of the 37 species are known in the Linton beds, and these, with the exception of *Pterinea spinosa,* which occurs at South Petherwin, and the doubtful *Spirifera hysterica,* Schloth., before alluded to, all pass up from the Linton group into the middle division of the system, either in Britain or on the Continent of Europe It would appear, therefore, that the chances against these rocks being Lower Devonian are as 35 to 2.

The fossil evidence respecting the position of the Padstow rocks is still more meagre; but as they are, I believe, admitted to be Middle Devonian, no question here arises. *Orthoceras Ludense,* Phill., which is also a Petherwin fossil, is said to be abundant here, and Goniatites are stated to occur*.

* Pattison, Trans. Roy. Geol. Soc. of Cornwall, 35th Ann. Rep.

It must be admitted that the connexion between the rocks of the Liskeard and Looe-river range, on the one hand, and those of South Petherwin, on the other, by means of their fossil contents, does not appear at first sight to be very strong; but the lists of species compared are small, and of that of the southern areas one-third of the species are in common. Moreover it must be remembered that nearly the whole of the Petherwin fossils come from the single locality of Landlake; a few occur in the quarry at South Petherwin; but the other limestone deposits are unfossiliferous, a very few only occurring in the slates above them, and the continuation of the range to the coast affords only the following species:— *Petraia Celtica, Phacops latifrons*, Pterinea subradiata*, Strophalosia productoides*, Rhynchonella pleurodon, Spirifera disjuncta†*, and var. *gigas*, and *inornata**, and *S. speciosa**. With the exception of the latter, these are all Petherwin fossils. Nevertheless we arrive at the conclusion that the Petherwin beds are not high up in the series, even from these data (independently of stratigraphical considerations), from their palæontological connexion with the higher group being so much less strong than it is with the middle group.

The unequal distribution of organic remains above alluded to in reference to the Landlake quarry appears to obtain very generally throughout the Devonian rocks of South Devon, although not always to the same extent; and it is, perhaps, what might be partly expected when we take into consideration the isolated position of many of these calcareous deposits; for whether we assume their coral-reef origin or not, they are still patches separated by intervals, more or less considerable, of, probably, muddy sea bottoms. Mr. Godwin-Austen, long ago, drew attention to this local association of genera and species‡, one form of Cœlenterata prevailing in one locality, while another is the dominant species in a neighbouring one. Some of these calcareous deposits appear to contain little else than one or two species of Corals and a few Amorphozoa. Others teem with Brachiopoda like those of Woolborough and Barton. At the same time the limestones of Woolborough, Ogwell, and Barton have been, no doubt, more diligently searched, especially Woolborough, and for the reason, as Mr. Godwin-Austen states, that the fossils at that quarry are extracted more easily and in better condition than at any other, and it is therefore a favourite spot of collectors. But the Woolborough colony is in fact no less remarkable than that of Landlake, and has alone afforded 139 species. Woolborough and Barton are equally rich in Brachiopoda, viz. 38 species, but only 26 species are common to the two localities. Woolborough has 20 Brachiopods in common with Dartington, 19 with Hope's Nose, 18 with Plymouth, and 13 with Ilfracombe. Barton has 18 Brachiopods in common with Dartington, Hope's Nose, and Plymouth respectively, but only 10 with Ilfracombe §. Nevertheless all these localities are in Middle Devonian

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* Mus. Geol. Soc.   † Mus. Pract. Geol., Jermyn St.
‡ *L. c.* p. 465.
§ Vide Mr. Pengelly's tables, Trans. of the Devonshire Association for the Advancement of Science, Literature, and Art, 1867.

rocks, and, with the possible exception of Ilfracombe, are all on the same horizon.

The abundance of species of *Cyrtoceras* at the Woolborough quarry is quite as remarkable as that of species of *Clymenia* at Landlake. Of the 13 species ʼwhich have been found at Woolborough, 9 are peculiar to the locality. One, *Cyrtoceras rusticum*, occurs likewise at Landlake, and three species occur in the Middle Devonian rocks of continental Europe. The Tetrabranchial forms, therefore, constitute a colony singularly restricted in range, and in consequence of these and the many other peculiar forms of extinct life associated at this spot, it has been suggested that this small mass of limestone, which here protrudes through the Culm-measures, may be of a different age from the rest of the Torbay limestones; and that the Woolborough and Landlake beds may have been synchronous, and referable to the lower part of the Upper Devonian series *. Against this view it may be urged that not one of the 13 species of *Cyrtoceras*, and only one of the 11 species of *Clymenia*, and one only of the 4 species of *Goniatites* met with in one or other of these two localities are known to occur in Upper Devonian rocks in any area.

But there is another and more fatal objection to this view, inasmuch as it assumes the existence of a fault with a downthrow of several thousand feet, and of course of an extent proportionate to such an effect; whereas there are only a few small faults in the vicinity with a throw of a hundred feet or so, perhaps less; for the Connator fault, if continuous with that of Bow Hill at all, has the downthrow on the other side, towards Ogwell and Ipplepen, or what amounts to the same thing, an upcast on the east, *i. e.* on the Woolborough side.

No further than Marldon, a few miles to the south, we see the Torbay limestones overlain by a great thickness of red slates and grits almost devoid of fossils; and the character of the rocks which overlie the upper limestones of South Devon is further seen in the succession of beds southward of Brixham, where they attain a thickness of several thousand feet; and there are not, and cannot be, any such faults as would cut out this great mass of red rocks and bring yet higher beds down among the Torbay limestones without producing more obvious effects than are visible on the country through which it passed.

The identification of the *Steganodictyum Cornubicum*, M'Coy, with the genus *Pteraspis* by the Rev. W. S. Symonds, of Pendock, which has since been confirmed by Prof. Huxley, has an important bearing upon the question of the age of the rocks of South Devon and Cornwall; for although it affords us no further aid by which to coordinate these rocks with any particular portion of the Old Red system, either of the Silurian area or of Scotland, the species being specifically different from any at present known in the Old Red, it throws additional weight on the views of those geologists who hold the two systems to be equivalent in time. The species is somewhat widely distributed; and I learn from Mr. Pengelly that it occurs at

* Salter, Quart. Journal Geol. Soc. vol. xix. p. 483, footnote.

intervals on the coast all the way from the mouth of the Fowey river to the towns of Looe, and thence along the shores of Whitesand Bay to the Rame Head, and up the river Towey to as far as Cliff and the parish of St. Veep.   I have found it in the slaty limestone of Milladon near St. Germans ; and Mr. Pengelly has met with it in Mudstone Bay, and at Bedruthen Steps near Padstow.   It ranges, therefore, through the whole of the beds from the calcareous rocks of St. Germans to the base of the Plymouth and Torbay limestones.   The genus, therefore, although more particularly characteristic of the Lower Old Red, appears to pass up*.   In the fine series of fish-remains in the collection of Mr. Pengelly, I noticed at least four or five other species, exclusive of the *Phillolepis concentricus,* all from the Looe-river group of beds ; and these remains appear to indicate an epoch during which, from their frequent occurrence, fish must have been abundant.

I leave the coordination of these rocks with the typical groupings of North Devon to those who are better acquainted with the latter, the chief object of this communication being rather to endeavour to establish the relations of the beds, or groups of beds, south of the Culm-measure trough among themselves ; and as regards the results, stated generally, they accord pretty nearly with those of the authors of the Devonian system as enunciated in the first of their memoirs †, although differing somewhat in details,—the whole of the beds, from the St. Germans and Ashburton range of limestones to the top of those of Plymouth and Torbay inclusive, corresponding with their group No. 2, the red argillaceous and gritty beds which are seen passing under the Triassic rocks of Painton, and which occupy in force the whole of the Kingsbridge promontory, exclusive of the metamorphic rocks, being represented by their groups 3 and 4.

But, assuming that the rocks included between the base of the Ashburton and the top of the Torbay limestones (the group No. 2 of Sedgwick and Murchison) represent the calcareous portion of the Ilfracombe group of North Devon ‡, then the red rocks of Blagdon Cross and the Kingsbridge promontory would in all probability correspond in position, as they do to some extent in lithological character, with the Upper and Morthoe portions of the same series ; while the rocks brought up around Hingston Down and in the vicinity of Buckland Monachorum would represent the lowermost portion of the Ilfracombe group, and the yet older rocks of St. Breock's Down would find their analogues in the Hangman Grits.

* Both *Pteraspis* and *Cephalaspis* occur in the Old Red high up in the Great Skirrid Mountain, and in the town of Abergavenny, in beds which, unless some great undiscovered fault exists, cannot be more than 1000 feet below the base of the Carboniferous slate of the South Welsh coalfield.

† *L. c.* p. 668, *et seq.*

‡ Vide Mr. Etheridge's Memoir, previously cited, pp. 604 & 605.

Legend

- Bovey Deposits
- Upper Greensand
- Trias
- Culm Measures
- Upper South Devon Group
- Lower South Devon Group
- Limestone
- Volcanic Rocks
- Metamorphic Rocks
- Granite
- Elvan
- Faults

Geological Map
of
SOUTH DEVON & EAST CORNWALL,
by
Harvey B. Holl, M.D., F.G.S.

SCALE OF MILES.
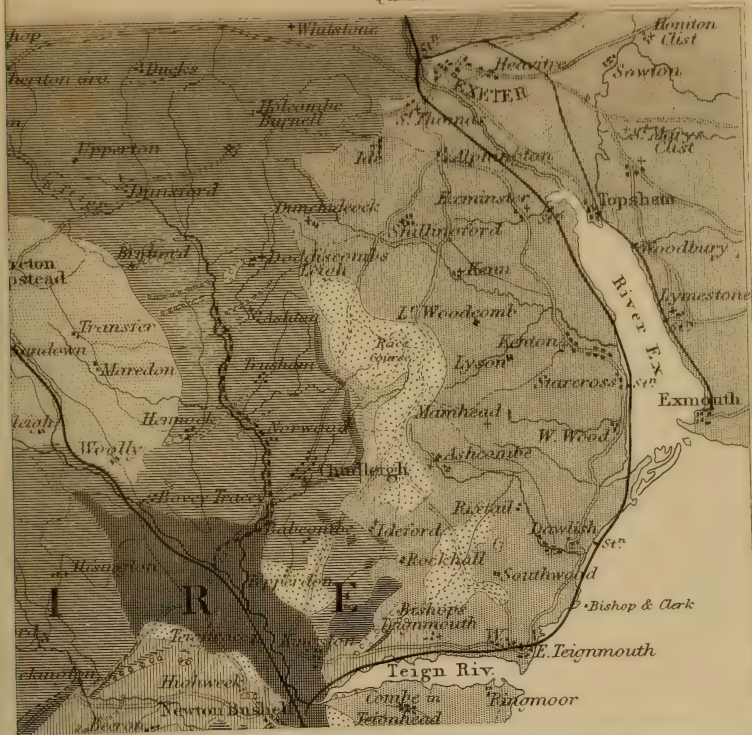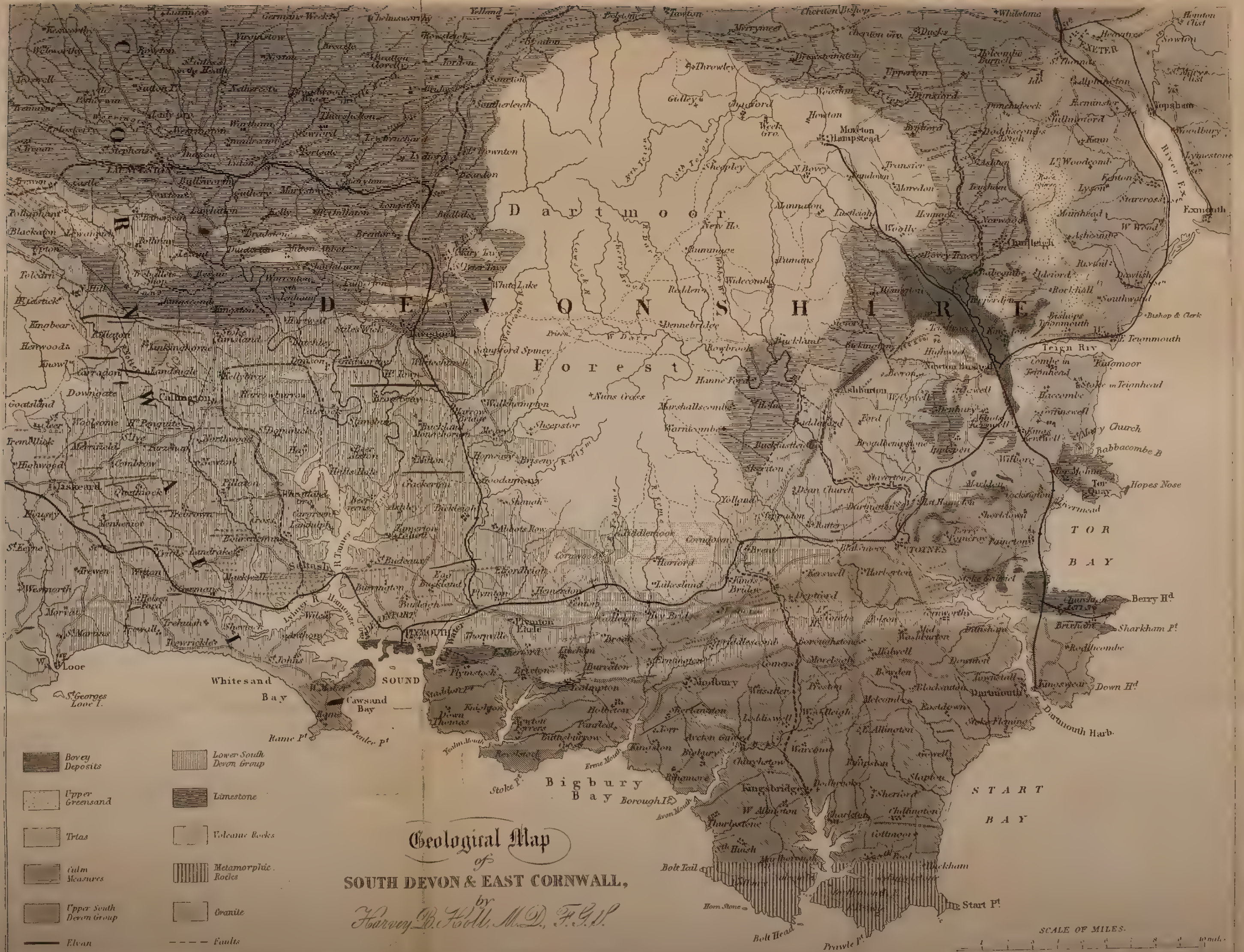
MAY 6, 1868.

The Rev. James Crombie, M.A., 84 St. John's Wood Terrace ; Charles Judd, Esq., A.K.C., F.R.A.S., 3 Stoneleigh Villas, Tottenham ; Duncan G. F. Macdonald, Esq., 4 Spring Gardens; J. S. Phené, Esq., 5 Carlton Terrace, Oakley Street, W. ; and M. Thomson, Esq., College House, Southgate, were elected Fellows.

The following communication was read :—

On the QUATERNARY GRAVELS of ENGLAND. By ALFRED TYLOR, Esq., F.L.S., F.G.S.

[The publication of this paper is unavoidably postponed.]

(Abstract.)

MR. TYLOR first compares the gravels of the Aire Valley at Bingley, of the Taff Vale between Quaker's Yard Junction and Aberdeen Junction, and of the Valley of the Rhonda near its junction with the Taff. He then describes the cave-section of Bacon Hole, Gower, and the sections exposed at Crayford, Erith, and Salisbury, comparing the angles of deposition of gravel-beds concealing the escarpment of the Chalk in these last three localities with the same conditions at Brighton and Sangatte.

By comparing the gravel-beds at different levels, and upon strata of different age and configuration, he shows in what respect they differ from each other.   The bulk and height of the Quaternary deposits have strengthened the conviction which he expressed in his previous paper (on the Amiens Gravel), that there was a long period, reaching nearly to the Historical epoch, in which the rainfall was excessive, and which he termed the " Pluvial period."

These sections also lead the author to the following conclusions :— (1) That the débris was deposited by land-floods, and that the mode of deposition was quite distinct from that of moraines produced by the melting of ice.   (2) That the character of the deposits in the valleys of the Aire, Taff, and Rhonda proves that they were formed under similar conditions.   (3) That these gravel-beds point to a Pluvial period of great intensity and duration.   (4) That the ice-action of which there is evidence was subordinate to the aqueous action.   (5) That the fossiliferous Quaternary deposits have been best preserved where they have been formed in cavities lying between the edge of the bank of a river, estuary, or sea and an escarpment running parallel with it at no great distance.   (6) That the immediate source of the gravels was the high land adjoining the rivers, whence they have been washed down by rain, with the assistance of lateral streams, into the lower ground, where they had come into contact with larger quantities of running water, had been mixed with rolled materials, and spread in thick beds over the bottoms and slopes of valleys or the sides of escarpments.   (7) That the surface of such a deposit rarely slopes at more than from 2° to 4°, while the slope of the beds lower in the series nearer the escarpment averages 12°. The escarpment is usually concealed under a coating of gravel or loess.

DISCUSSION.

Mr. PRESTWICH dissented from the view of the author, that the valleys had been excavated to their present depth before the gravels were deposited; and, with reference to a former paper, explained that Mr. Tylor and himself had taken different points of observation near Montiers, and that his own views as to the separation which in some cases may be shown to exist between the high- and low-level gravels were correct.

Mr. EVANS also combated Mr. Tylor's views, and pointed out the difficulty of accounting for deposits of gravel such as are at present found in valleys already excavated to their present depth.

Mr. W. BOYD DAWKINS objected to calling in hypothetical causes to account for effects when existing causes are sufficient, and cited the sudden melting of snow as a sufficient cause, as had already been suggested by Mr. Prestwich.

Sir CHARLES LYELL supported the same view, and mentioned a case which had occurred at Salisbury some 30 years ago as an instance of the effects of such floods. He also cited the existence of flint implements in the gravels on either side of Southampton Water as evidence of the existence of man during a long period of excavation of valleys. He also mentioned the discovery by Dr. Harris, Bishop of Gibraltar, of flint gravel identical with that of the present valleys beneath the Basalt of Miocene date in Antrim.

Mr. SEARLES V. WOOD, jun., insisted on the difficulty of increased rainfall filling even the old river-channels of Mr. Prestwich, far less entire valleys, as suggested by Mr. Tylor; and pointed out that such increase would so freshen the estuaries, that the valleys might have been excavated by tidal action, and yet yield freshwater remains.

Prof. ANSTED showed, by calculation, that even a vast increase in the rainfall would not suffice to fill the valleys so as to deposit the gravels as at present found.

Mr. WHITAKER quoted the existence of distinct terraces of gravel one above the other in the Thames valley as proving the gradual excavation of the valley.

Prof. MORRIS doubted as to the precise character and age of the deposits in the valleys in South Wales having been accurately ascertained.

Mr. Tylor briefly replied.

Prof. RAMSAY made some concluding remarks, expressing his disagreement with the views of the author as to the enormous magnitude of the ancient rivers.

MAY 20th, 1868.

The following communications were read :—

1. *On the* ERUPTION *of the* KAIMENI *of* SANTORIN. By Dr. J. S. JULIUS SCHMIDT, Director of the Observatory of Athens.

(In a letter to His Excellency E. Erskine, British Minister at Athens.)

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.]

DURING my first journey to Santorin, in February and March 1866, I communicated a general outline of this remarkable eruption, which commenced at the end of January 1866, and has since been visited and described by observers from different parts of Europe. These include the members of the Athens Commission, Messrs. Fouqué and Tauzen, Baron von Seebach, and Messrs. Fritsch, Reiss, and Stübel. From time to time information has been received on the subject, and everything has tended to show the extreme desirability of accurate measurements. Up to the close of 1867 the eruption continued without a day's (perhaps without an hour's) intermission. There has also been no cessation in the growth of the lava-deposit on the south side of the Nea Kaimeni, and there seems every probability that some years may elapse before the volcanic energy of the island will have altogether died out.

On the 4th January 1868 I arrived at Santorin, in the Austrian gunboat " Dalmat," commanded by Baron Wickede. We anchored at Bancho, a little to the east of Mikra Kaimeni. Here we remained until the evening of the 9th January, and were fortunate enough to complete our observations in very fine weather.

For want of instruments, my own observations were limited to temperature and to taking sketches of the recent formations. Many hours, both of the day and night, were occupied in determining the exact nature of the eruptions of the George volcano, and in approximately making out their periodicity.

The most essential part of the undertaking, namely, the mapping of the newly formed deposit, was entirely left to the Baron Wickede, who, between the 5th and 9th January, marked carefully with a good prismatic compass all the principal positions of the area in question. The officers of the Dalmat took the soundings and prepared the charts. On the 9th January, at my desire, Baron Wickede and Lieutenant Müller took trigonometrical measurements of the heights of the old cone and of the George volcano.

The extreme length of Nea Kaimeni was formerly 1800 yards, and the average breadth 800 yards. The eruption is well known to have originated on the south side of the island, in a small bay below the old volcano, and to have extended towards the west, throwing out a spur through the Aphroessa. It also destroyed and covered up a terrace on the south coast of Nea Kaimeni 300 yards wide and nearly 1000 yards long. The tendency of the lava-current was southward, sometimes flowing slowly, sometimes welling up ; but the advance was slow, the depth of water being 100 fathoms.

After about two years the extension towards the south was be-

tween 1200 and 1400 yards in length, the breadth being 1800 yards from west to east.   As, however, the additional mass also covers the southern extremity of the old land of Nea Kaimeni, the total dimensions of the mass from north to south amount to 1520 yards.   The new formation has the shape of a triangle, whose apex is directed towards the south, and is from 90 to 100 feet above the sea, with steep inaccessible walls, which towards the south still show indications of movement, and still have a high temperature.   I find by calculation that the area of Nea Kaimeni, which before 1866 amounted to $9\frac{1}{2}$ millions of square feet (220 acres) has since been increased by $13\frac{1}{2}$ millions of square feet (310 acres).   Thus the present eruption has done much more in two years than did the eruption of last century in five years.   On account of the great depth of the water, and the continual access of the open sea, the temperature of the water near the coast has not been remarkable, ranging between 77° and 122° F. In fissures of the lava, however, the temperature of the water is not unfrequently 158° F.   At the northern foot of the old cone, and in the neighbourhood of the former mole, thermal springs rise at the level of the sea, whose temperature in January 1868 was from $135\frac{1}{2}$° to 140° F.   At the eastern side and towards the southernmost extremity of the new deposit, there are still numerous white fumaroles.   There are others like them, but on a smaller scale, at the top of the old cone.   Of the four islands of the 4th May there are now only three visible.   They are composed of rock of a deep-black colour, glassy and fine-grained, but not altogether like obsidian.   On the westside of Nea Kaimeni, the old George Harbour has been greatly improved by the new rock upheaved on the southern and western sides. It is now from eight to nineteen fathoms deep, and safe even for large ships.   On the other hand, the channel between Nea and Micra Kaimeni is now much encroached upon from the eastern side, and shallowed to two fathoms, so that it is only passable for boats.

It is known that the eruption of 1866 commenced with a depression of the bottom of the volcano-harbour.   In February of that year I was informed by Herr L. Palassa of the splitting and sinking down of the old cone, and also of the gradual subsidence of the mole on the northern foot of the hill.   In January 1868 we found the mole quite under water, and almost entirely invisible, and all the buildings around already partly submerged.   The depression of the old cone had advanced very manifestly since 1866, and the whole southern side of the Micra Kaimeni had shrunk so much that I estimated the result at not less than three feet.   In Palaia Kaimeni I could find no satisfactory evidence of similar subsidence ; and in George Harbour, on the western side of Nea Kaimeni, the result was also slight.   The Aphroessa has long since disappeared ; and I have not even been able to recognize its precise position, on account of the great development of the lava towards the south-west.

The " George " volcano is at present higher than its northern neighbour, the old cone undergoing subsidence.   Its height is about 325 English feet.   It is a very regular hill, with a slope of from 30°to 32°, and is everywhere covered with ashes.   It sends out a spur

towards the south, which is of a reddish-brown colour, and has numerous fumaroles, this spur much resembling that which projects from the old cone towards the north-west. The summit is truncated, and exhibits a large shallow crater with many holes, from which from time to time issue the eruptions of ashes that cover the surrounding district. A low cone rises out of the crater; and from openings in this a glowing red light is seen even in the daytime. This cone is subject to upheaval and depression in a very singular manner, being acted on by the irregular eruptive force. I shall take another opportunity of alluding to these oscillations, as observed by the telescope from a distance. Surrounding the base of the George cone, stretches a broad ring of large erupted stones that have rolled down the slope. On the dark ground of the slope are streaks of lighter colour radiating from the top, and composed of white pumice and small light-coloured fragments. On the west side dolerite appears, of red-brown, violet, and even greenish colour, reduced to the condition of cinders or volcanic ash (lapilli) by the action of fumaroles, which break out there and on the outer ring of the crater.

The eruptions are tolerably frequent, generally magnificent in appearance, and can be seen in fine weather from most of the Cycladian islands. I watched several on the 30th December, 1867, from the hills of the island of Syra, a distance of 70 geographical miles. Generally there is an eruption of stones and ashes at intervals of six or seven minutes; but sometimes the intervals are from ten to thirteen minutes. If we regard the great eruption of February 1866 as of the first rank, all those that we observed in 1868 must be regarded as of the third to the fifth rank. There are now also intervals of complete rest lasting many minutes. The eruptions of ashes and stones take place very suddenly, sometimes with dull rumbling noises, sometimes with a sharp explosion, and sometimes, though rarely, resembling a discharge of heavy artillery, at the distance of a mile from the spot where the observer is stationed. Immediately after the eruption of ashes, rushing and hissing columns of white steam succeed, and these are followed by faint yellow noiseless issues from the central fumarole. None of the stone-showers, and no single red-hot stones are thrown more than 400 feet above the crater. At night the intensity of the volcanic fire derived from the combination of red-hot stones, hot and glowing ashes, and columns of steam (comparatively unimportant) presents a grand spectacle for contemplation. There were, however (at least so far as could be made out by the telescope), no indications of real flame, such as were so distinctly seen and so well described in 1866. We observed occasionally at night, from the sea, on the surface of the still moving lava, a few red spots (blocks still glowing), but on no occasion any true flame.

The quantity of ashes that have been ejected since 1866 is considerable; and the irregular summit of the old cone, as well as that of Micra Kaimeni, are on this account hardly to be recognized, and cannot be traversed everywhere without danger. The ashes are for the most part black, fine-grained, and full of very fine pores; once, however, they were white, soft, and dusty. With a fresh west wind

blowing, it took two and a half minutes to bring the ashes from the crater as far as our ship, a distance of 1400 yards.

It is impossible to predicate anything at present with regard to the cessation of the eruption, although if its present state is compared with that of 1866 it will be found to have changed several times, and to have diminished in intensity. The apparent slowness of the advance towards the south is due to the depth of water, which is more than 30 fathoms. For some years the Santorin eruption will reward observers. I must postpone to a future day my numerous notes, observations, and measurements, and at present only offer this general notice of the present state of the volcano.

DISCUSSION.

CAPT. SPRATT pointed out that this was only one of the many peaks in the centre of the large crater of Santorin, which have risen up since the historical period. In the position in which he had anchored but six or seven years ago there is now a hill upwards of 300 feet in height, according to the latest Admiralty survey of the new land at Nea Kaimeni, dated October 1867.

Sir RODERICK MURCHISON referred to the communications to the French Academy relative to the chemical products of the eruption, and their relation to those of Vesuvius and other volcanoes.

Mr. FORBES directed attention to the fact alluded to in the late President's Anniversary Address, that the lavas of this volcanic outburst were, at its commencement, trachytes, or of highly silicated character, but afterwards were basic lavas, thus proving that rocks of totally different characters and chemical composition (respectively analogous to the granitic and trappean rocks of former periods) might proceed from a volcanic focus during an eruption.

Prof. ANSTED called attention to the probable connexion of the eruptions in these islands with those of Vesuvius and Etna, and mentioned that Baron von Waltershausen had presented to the Society photographs of his magnificent original drawings of the whole region of Etna, which were upon the table, and of which only three copies were taken on a larger scale than the published maps.

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2. On the STRUCTURE of the CRAG-BEDS of NORFOLK and SUFFOLK, with some OBSERVATIONS on their ORGANIC REMAINS.—Part II. The RED CRAG of SUFFOLK. By JOSEPH PRESTWICH, Esq., F.R.S., F.G.S.

[The publication of this paper is unavoidably deferred.]

(Abstract.)

THE superposition of the Red Crag to the Coralline having been clearly shown by previous writers, the author confines his paper to those questions on which differences of opinion still exist, namely, the structure of the Red Crag, its affinities with the Coralline, and its exact relation to the Mammaliferous Crag of Norfolk. The Red Crag of Suffolk is described as occupying an excavated area in the Coralline, wrapping round the isolated reefs of the latter, filling up

the hollows between them, and occupying a similar, and sometimes a rather lower level than the summits of these older reefs. It forms such an extremely variable series of beds, that the author has been unable to observe any definite order of succession in the greater part of it; but he remarks that oblique lamination is most strongly developed in the lower and central portions, and that almost everywhere there occurs at the base a bed of phosphatic nodules, although deposits of that nature are by no means confined to one level. Old sea-cliffs of Coralline Crag, and remains of old sea-beaches at their base, are described by Mr. Prestwich as occurring at Sutton; and he also gives detailed descriptions of the numerous pits in the Red Crag of Suffolk where the phenomena which he describes may be observed. Dividing the Red Crag into an upper, frequently unfossiliferous member (the fossils of which, being most frequently in the position in which they lived, may be regarded as truly representing the fauna of the period), and a lower, fossiliferous portion (in which the shells are found mostly in a broken and comminuted state, and mixed largely with fossils derived from the older Coralline Crag), the author describes their distribution in Suffolk, and their mode of occurrence on the eroded Coralline Crag, referring more especially to the difficulty in drawing the line between them in many cases.

In treating of the organic remains of the Red Crag, Mr. Prestwich gives lists of the shells found at the different localities, which had been prepared with the aid of Mr. Gwyn Jeffreys. Taking the local conditions into consideration, eliminating the extraneous fossils of the Red Crag of Sutton, Butley, &c., and excluding the freshwater fossils of the more northern districts, the author regards the remaining fossils of the two divisions of the Red Crag as being so closely related that the whole group must palæontologically be treated as one. Mr. Searles Wood has given the total number of species of its Mollusca as 239; to these Mr. Gwyn Jeffreys has added six additional species; on the other hand, he regards ninety-nine of them as varieties and extraneous fossils, leaving 146 species belonging to the Red Crag. Of these Mr. Jeffreys has identified 133, or 92 per cent., with living species, 115 still being inhabitants of British seas, 15 being found in more northern seas, and 3 in more southern.

From the Mammaliferous Crag of Norfolk and the Red Crag of Suffolk never having been found in superposition, from the circumstance that just at the point where the latter ceases the former begins, as well as from the community of so many species of organic remains, the author regards the two deposits as equivalent; and he attributes their distinctive characters partly to the extraneous fossils in the Red Crag, and partly to the difference in the conditions which prevailed in the two areas at that time, and especially to the more littoral and brackish-water conditions which prevailed in the Norfolk area. In conclusion, Mr. Prestwich gives a sketch of the physical history of the Red-Crag period, describing the mode in which the various phenomena which he notices have been produced.

DISCUSSION.

The Rev. Mr. GUNN, in opposition to the view of the forest-bed being placed above the Chillesford Clay, mentioned that at Easton Bavent, where the latter has been supposed to occur in the cliff, he had seen the forest-bed exposed on the shore. He instanced other cases where the forest-bed, in his opinion, underlies the Chillesford Clay and Sands, and supported his views by the evidence of the Mammalian remains of the different beds, and especially the succession of the *Mastodon Arvernensis*, the *Elephas meridionalis, E. antiquus*, and *E. primigenius*. He regretted the absence of any mention of the Mammals of the Red Crag.

Mr. GWYN JEFFREYS made some remarks on the subject of species, and explained how, from a comparison of a large number of specimens, he had in many instances been led to reduce what had formerly been considered distinct species into mere varieties of the same species. He corroborated the views of the author as to the presence in the Red Crag of numerous fossils of the Coralline Crag.

Dr. COBBOLD stated that, from a microscopic examination of the phosphatic nodules, he had established the existence in them of Radiolariæ and Diatomaceæ, and especially of *Arachnoidiscus cocconeis*, the Radiolariæ being chiefly of the division Acanthometræ, all three forms being purely marine.

Mr. CHARLESWORTH commented on the remarkable fact that in a few thousand square feet of Coralline Crag we have a fauna as extensive as the whole British Molluscan fauna. He considered that at present the attempt to solve the question of the age of the Red Crag was hopeless, mainly from the difficulty of recognizing extraneous fossils. He expressed his disappointment at the fish-fauna of the Red Crag not having been noticed by the author. The teeth which were common to the Eocene and Red Crag had usually some phosphatic matter adherent. Those, on the contrary, which only occur in the Crag, never have any phosphatic matter attached. He therefore regarded the former class as derivative, but the latter as belonging to the deposit in which they occur.

Mr. SEARLES WOOD, jun., denied that the Red Crag was the one homogeneous deposit divided into two beds represented by Mr. Prestwich; he protested against the Walton and Butley deposits being regarded as one and the same, the former bearing more affinity to the Coralline Crag, and being therefore probably the older.

Mr. PRESTWICH, in reply, explained that he did not intend to omit the list of Mammalian remains of the Red Crag, tables of which were appended to the paper; the greater part of them, however, he regarded as derivative. With regard to the relation of the Chillesford beds to the forest-bed, he had never *seen* a section in which the latter underlies the former; the Chillesford beds at Easton Bavent are underlain by sandy beds referable to the Norwich Crag. He considered that some division in the lower bed, as suggested by Mr. Searles Wood, was to be found.

June 3, 1868.

M. Albert Gaudry was elected a Foreign Correspondent.

The following communications were read :—

1. *On some* CARBONIFEROUS CORALS.　By JAMES THOMSON, Esq.,

[Communicated by Dr. P. M. Duncan, F.R.S., Sec.G.S., &c.]

[Abstract.]

IN the 'History of Rutherglen and East Kilbride' by the Rev. D. Ure, Parish Minister of East Kilbride, in Clydesdale, there is figured a cup-coral, the description of which refers only to the external form, and the name given to it was simply *Fungites*.　Since then it has received various names from the following writers :—

Fungites, Rev. D. Ure, Hist. of Ruth. & East Kilb. p. 327, pl. 20. fig. 6 : 1793.

Turbinolia fungites, Flem. Brit. Anim. p. 510 : 1828.　S. Woodward, Syn. Tab. of Brit. Org. Rem. p. 7 : 1830.

Cyathophyllum fungites, Geinitz, Grund. der Verst. p. 571 : 1845-6.

Clisiophyllum prolapsum, M'Coy, Ann. & Mag. Nat. Hist. 2nd ser. vol. iii. p. 3 : 1849.

Aulophyllum prolapsum, Edw. & Haime, Brit. Foss. Corals, Introduction, p. 70 : 1850.

—— *fungites*, Edw. & Haime, Pol. Foss. des Terr. Paléoz. p. 413 : 1851.

Clisiophyllum prolapsum, M'Coy, Brit. Palæoz. Foss. p. 95, Pl. 3 C, fig. 5 : 1851.

Recent investigations into the internal structure warrant us in dissociating it from any of the generic names it has received, and raising it to the rank of an independent genus with a descriptive title.

The author then gave descriptions of the genera *Cyathophyllum*, *Clisiophyllum*, and *Aulophyllum*, and of the new genus, *Cyclophyllum* (Duncan and Thomson).

The characteristics of each of these genera are sufficiently marked to warrant their generic distinction.

The ascending convex vesicular dissepiments in the middle area, the mesial columella in the vertical section, and consequently the exserted conical boss in the centre of the calice separate the genus *Clisiophyllum* from the other genera of Cyathophyllidæ.

It differs from *Cyathophyllum* in the latter having no columella, the columellar space being filled up by closely set tabulæ.

In *Aulophyllum* the tube-like mass in the centre of the corallum is occupied by minute tabulæ.

DISCUSSION.

Dr. DUNCAN said that the existence of a columella was a generic distinction in recent and mesozoic corals, that the type of the palæozoic Cyathophyllidæ was reflected in the Lower Liassic coral-fauna of South Wales and the west of England, and that there was a

necessity for the same principles of classification in the palæozoic and in the recent coral-fauna. There was a gradation from the Rugosa to the Aporosa.

Prof. HUXLEY remarked that the structures of the specimens of the different genera proved that there were great difficulties in accepting Agassiz's opinion that these old forms were not *Zoantharia*.

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2. *On the* PEBBLE-BEDS *of* MIDDLESEX, ESSEX, *and* HERTS. By SEARLES V. WOOD, Jun., Esq., F.G.S.

IN the manuscript memoir which, in May 1867, I placed in the Library of this Society, illustrating the Geological Survey I had made of that part of the Thames-valley region which is comprised in sheets 1 and 2 of the Ordnance Survey-map, I entered in some detail upon the subject of certain pebble-beds which I referred to the age of the Bagshot Sand; but being anxious to compress as far as possible the paper on the Postglacial structure of the east of England referring to that memoir, which is printed in the 23rd volume of the Society's Journal (p. 394), I made no allusion in it to these beds. A late communication to the Society by Mr. T. M'K. Hughes, on the two plains of Hertfordshire and their gravels*, induces me to lay a brief notice of them before the Society.

The beds so referred by me are composed almost exclusively of rolled flint pebbles, with a few of jasper intermixed, not a pebble of any other material being present except at one locality, " College Wood," one mile and a half north-west of Frierning, where I found many quartzites of similar rolled form to occur in them. The composition, form, and structure of these beds much resembles the well-known pebble-bed beneath the London Clay, regarded by Mr. Prestwich as a local modification of the basement bed of that clay, the principal difference being the absence of the smaller and spherical pebbles so numerous in the latter, and in the absence of the beached condition which that bed in one or two localities presents. The peculiar feature attaching to the beds under consideration, in addition to their almost exclusively flint composition, is that they are invariably present where any of the Lower Bagshot Sand remains, and never occur except on the numerous outliers of that sand which are scattered through South Essex†. They have often a considerable admixture of clay; and where they occur on the Bagshot outlier at Stock, in Essex, the section shows the pebbles in the form of bands imbedded in laminated clay. They often, but not invariably,

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* Quart. Journ. Geol. Soc. vol. xxiv. p. 283.
† I should explain that in speaking of the Lower Bagshot of Essex, I have treated the uppermost bed of brick-earth and the sand below it as included in it, regarding the London Clay as terminating at the junction of that sand; and my mapping of this formation is on that principle. A thin bed of dark sand occurs *in the London Clay itself*, about 50 feet from the top of that formation, which I met with in several places, and is quite distinct from the sand which terminates the London Clay.

rest, with a well-defined line of division, and somewhat unconformably, upon the Lower Bagshot Sand ; but sometimes they appear to be interbedded with the upper part of that sand itself.   Although the Glacial Clay is in several parts in the closest contiguity to these beds, the two have obviously no connexion with each other, since the former lies up against the pebble-beds, and occupies slight depressions eroded through them, as at Pilgrim's Hatch in the accompanying section.   Nothwithstanding their close contiguity to the Glacial Clay, *the pebbles never rest upon it*, and are thus shown not to be of Postglacial age ; while their constituent material, rounded condition, and places of occurrence equally remove them from any connexion with the Middle Glacial Gravel.   These features, found to be constant over all the tableland on the north of the Thames, have for several years past induced me to regard the beds in question as not improbably of Eocene age, and, from their invariable association with the Lower Bagshot Sand, as having belonged either to the close of that formation, or else as representing in these parts the Middle Bagshot of Surrey.   In either case their bearing upon the geographical changes during the Eocene period would be the same, since they would thus indicate that the final recession of the Eocene sea from Middlesex and Essex was coeval with the commencement of the rich fossiliferous marine, estuarine, and freshwater series of Hampshire, which, geologists seem agreed, took place at the close of the Lower-Bagshot period.

The association of these pebble-beds with this event, however, is only a provisional one, and one adopted for want of some satisfactory evidence of the occupation of Middlesex and Essex by the sea between the Lower-Bagshot-Sand period and the Glacial.   The principal point connected with these, to which I desire to call attention, is their disconnexion with the gravels either of the Glacial or Postglacial series, and more particularly their distinction from the gravel, principally made up of pebbles (but of which many are broken), *that underlies the Glacial clay at high levels*, lately described by Mr. T. M‘K. Hughes as " Gravel of the Higher Plain of Hertfordshire."

If the evidences upon which Mr. Prestwich relies as indicative of the denudation of the Eocene Tertiaries over a portion of Kent, and the occupation of that denuded area by the sea during the period of the Coralline Crag, or of some anterior part of the Diestien Series, were sufficiently unequivocal to justify us in assuming that the Coralline Crag, or some yet older Pliocene, or some newer Miocene sea washed a dome of chalk protruding through the lower Tertiaries, we might associate the pebble-beds which thus invariably accompany the Lower Bagshot outliers with such a geographical feature, and refer them to the older Pliocene, or newer Miocene period.   We may fairly assume such an age as one of the possibilities connected with them ; for the somewhat unconformable position which the pebbles occupy relatively to the Lower Bagshot on which they rest would assist their separation from the Bagshot series ; and could the presence of the sea over Kent during the Dies-

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tien period be established, the reference of the pebble-beds in question to that period would perhaps be the most probable hypothesis that we could adopt. Nevertheless the great extent of country which the range of Bagshot outliers show these beds, uncovered by any other deposit, once to have occupied is more consonant with what we should suppose would result from the desertion of an area by a preexisting sea than from the occupation of it by a new one, because such beach-rolled pebbles as these imply very shallow conditions during their accumulation, and an advancing sea would form other deposits as it progressed over the pebbles which had first accumulated along its margin, and of these we find no trace ; whereas a receding sea (such, for example, as that which had already deposited the Lower Bagshot Sand) would accumulate successive fringes of pebbles along its margin as it receded, which would, as the sea abandoned them, be left uncovered by any other deposit. Looking at the features which obtain over the area dividing these pebble-beds from the Red and Coralline Crag area of Suffolk, nothing is presented which would connect itself with them in that direction. Should their accumulation, therefore, have been due to an older Pliocene sea, that sea must, I submit, have been one occupying the south of England, and connecting itself with the older Pliocene of Normandy mentioned by Sir Charles Lyell [*], or with the newer Miocene of Touraine, and not with any in the direction of Suffolk.

The pebble-beds in question occur in Essex on the Bagshot at Brentwood, Shenfield, and Warley (where they are in their greatest thickness, approaching 20 feet), and at Highbeach and Jack's Hill, to the south-west of Epping. At Norton Heath, near Ongar, they are present on a small exposure of Bagshot Sand which rises as a boss through the Glacial Clay. They are also present on the Bagshot at Frierning Church, and in the woods two miles north of it, in Writtle Park Wood (two miles further east), at Stock, at Billericay, at Kelvedon Common, and near Bentley Mill—also between Pilgrim's Hatch and South Weald, at Havering, and on Langdon Hill. I also found slight traces of them on the Bagshot at Lambourn End, near Chigwell, and at the opposite extremity of the county, on the Bagshot at Rayleigh. A very similar bed of pebbles occurs on Galleywood Common, near Chelmsford (where slight traces of the base of the Bagshot Sand occur), the Glacial Clay lying close up against them, but never underlying them. Their occurrence in Middlesex is confined, so far as I know[†], to Hampstead Heath, where traces of them are visible distributed over the surface of the extreme summit of the Lower Bagshot outlier there, their present position there being apparently due to redeposit by the Postglacial denudation ; but they are in decided contrast to the small patch of fine Postglacial angular gravel hard by, on which the fir trees near "the Spaniards" grow. I have not visited the Lower Bagshot outlier on Sheppey ; but, according to a paper by Mr. Weston, in the 10th

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[*] ' Manual,' 3rd ed. p. 166.

[†] Mr. Prestwich informs me, however, that a bed of rolled flint pebbles caps the Bagshot outlier of Harrow.

volume of the Quarterly Journal, rounded pebbles are scattered over this outlier also. We derive no assistance in the reference of these beds to their true geological age from organic remains, as they appear to be entirely destitute of anything of the sort.

It is important to observe that some of the earliest Postglacial gravels have been chiefly made up of these beds redeposited; and in such form they are sometimes difficult of distinction from the original bed. These redeposited pebbles may, however, usually be distinguished by the presence among them of angular flints, derived from the denudation of the Glacial Clay; but as the two sets of gravels are often in conjunction, without any distinct line of demarcation, care is required not to confound them, almost every mass of these older pebbles being overlain by a few feet of Postglacial pebble-gravel, which, though made up of the redeposit of the older bed beneath it, contains an intermixture of stones derived from various rocks. The pebbles of the beds which I have first described, namely, those invariably associated with the Bagshot outlier, and numbered 4, have also been redistributed by the Postglacial denudation in the form of feeble gravels, and gravelly warp, over the London Clay and passage-beds—their chief places of occurrence in this form being at Hawk's Hill Wood, Ongar Park Wood, Tawney Wood, and Beachet Wood, all on the east and south-east of Epping in Essex. These feeble gravels and gravelly warp *are omitted from the section accompanying this paper*.

In addition to this the pebble-beds (No. 4) appear to me to have formed the principal source of the pebbly gravel which, in an intermittent way, underlies the Glacial Clay in places where that clay is at high elevations in Essex, Middlesex, and Herts; this pebbly gravel is that described by Mr. Hughes as the "Gravel of the Higher Plain," and is shown in the accompanying section by the number 6. The distinction of this from the more extensively distributed Middle Glacial gravels, which similarly underlie that clay (but in these counties at lower elevations), I also pointed out in the memoir before referred to. The same desire to compress, however, caused me to omit from the paper on the Postglacial structure of the south-east of England any reference to them, beyond a symbol * indicative of their place in the diagram-sections, which were given in that paper (vol. xxiii. p. 396) for the purpose of showing the mode in which the incidence of the Glacial Clay took place over the area now forming the northern heights of the Thames valley. The occurrence of what I deem the same bed in Herts having, however, formed the subject of the paper of Mr. T. M'K. Hughes, before referred to, I think it desirable to advert here to what I believe, from a study of it in the parts lying beyond that embraced in Mr. Hughes's paper, to be its age and origin, having come to a different conclusion on this point from that gentleman.

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* See bed 6' in figs. 2 & 3, p. 396, of the 23rd vol. of the Quarterly Journal; unfortunately, by a typographical error, that symbol is omitted in the descriptive reference to those diagrams, and should come in between the words "clay" and "occasional" in the description of bed No. 6 in those diagrams.

I should premise first, by bearing testimony, so far as my own observations extend, to the careful and precise delineation of these beds as distinguished from the Middle Glacial Gravel, termed by him "Gravel of the Lower Plain," which Mr. Hughes has made, so that there can be no confusion as to the actual bed intended to be discussed, since we found our respective lines, where the districts examined by us joined, to fit exactly; and secondly, by pointing out that "this Gravel of the Lower Plain" is the same bed as that which, in the form of gravel or of sand, I have traced as extending in a tortuous track (due probably to its being a deposit of narrow channels) beneath the great Boulder-clay (or Upper Glacial formation) through Hertfordshire and Bedfordshire as far as Buckinghamshire and Leicestershire on the north-west, and as emerging in a broader sheet from beneath this Boulder-clay, over much of Essex, Suffolk, and Norfolk. Some years since, I pointed out that this sand passed over the entire series of beds which form the Cromer-coast section, the uppermost of which is the well-known contorted drift, and the whole of which series (termed by me Lower Glacial) seems confined to Norfolk and the north of Suffolk *. Since then I have been engaged in regularly mapping the Glacial series over Suffolk and Norfolk in conjunction with Mr. Harmer of Norwich, and we have found abundant confirmation of this order of superposition being correct; and I should observe that at the base of this Middle Glacial sand and gravel, and resting upon the uppermost member of the Lower Glacial series, namely, upon the contorted drift, there occurs, a few miles west of Lowestoft, a similar bed of Boulder-clay to that described by Mr. Hughes as occurring at the base of the Lower-Plain Gravel in Hertfordshire. I should further mention that from gravel at Stevenage in Herts. in the midst of the brickearth-beds so accurately described by Mr. Hughes as intercalated in this Middle Glacial formation, I procured several specimens of *Ostrea edulis,* a non-arctic shell which died out in the newer beds of the Crag, and is unknown in the Lower Glacial series, and that Mr. Harmer and myself have also obtained a Molluscan fauna of twenty-six species from this middle division; but, as we hope hereafter to lay what we regard as the structure and fauna of the Glacial beds of Norfolk and Suffolk before the Society, I need not here refer to them further.

Now the pebble-gravels (termed by Mr. Hughes "Gravels of the Higher Plain") occur on the highest London-clay summits, that extend southward, from the termination of his section at Brickenden Green, towards the Bagshot outliers of Hampstead and Harrow; and, although there remains no Glacial Clay over them, there can be little doubt, I think, of these patches being a continuation of this "Gravel of the Higher Plain." At Finchley, however, some 100 feet or so lower than the summit of the Bagshot outlier of Hampstead (on which occur, as before mentioned, traces of the same pebble-beds as those first described, and distinguished by the figure 4 in the accompanying section), we find this Gravel of the Higher Plain

* See also the diagram-section at pp. 548 & 549 of the 22nd vol. of the Society's Journal.

Section from Brickenden Green to the Brow of the Thames Valley near Brentwood.

W.N.W. — E.S.E.

Valley of the Lea.

Brickenden Green. — Bencroft Wood. — Beaumont Green. — Applebury Cottage. — Cheshunt. — Waltham Abbey. — The Wake Arms, Jack's Hill. — Theydon Gate. — Theydon Mount. — Stapleford Tawney. — River Roding. — Navestock Heath. — Pilgrim's Hatch. — Brentwood Cutting. — Brow of the Thames Valley at Warley Gap.
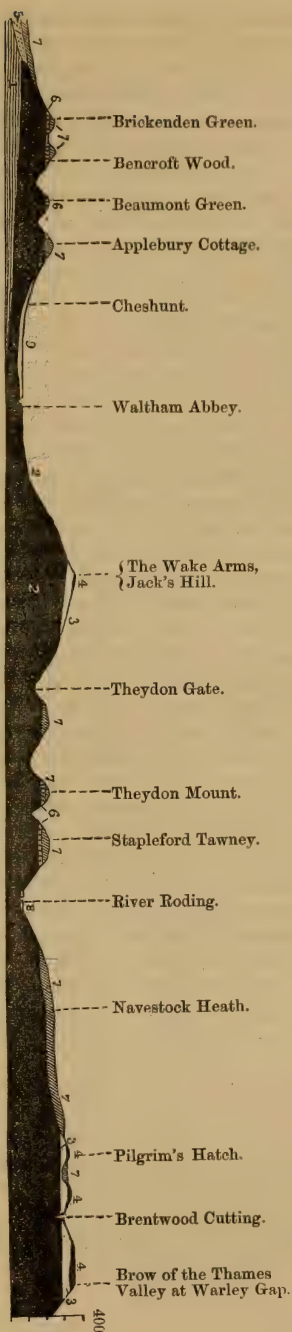
1. Lower London Tertiaries and chalk. 2. London Clay. 3. Lower Bagshot sand. 4. The Pebble-beds. 5. Middle Glacial Gravel (or Gravel of the Lower plain of Mr. Hughes). 6. Pebbly Gravel (or Gravel of the Higher Plain of Mr. Hughes). 7. Upper Glacial (or "The Boulder-clay"). 8. Postglacial gravel of the Roding valley. 9. The Lea-valley branch of the Thames gravel (Postglacial). Length of Section 22 miles, the vertical scale is in feet, and approximate only. The section traverses old depressions in which the Glacial beds have been deposited; but the existing valleys are shown by it to have been excavated independently of these depressions.

in situ beneath the Glacial Clay, its occurrence here having been brought before the Society as far back as 1835* by Mr. Spencer. That gentleman, however, speaks of it only as composed of flint-pebbles and sand; and when I saw the bed exposed, a few years back, during the progress of the railway works, it appeared to me almost wholly made up of sand and flint-pebbles, the quartz and quartzite fragments being unfrequent. The same constitution appears to me also to mark the bed as it occurs in the patches over the London-Clay summits before described, as, *e.g.* at Barnet, Totteridge, Hadley, &c. In the south-easterly direction from the district described by Mr. Hughes, this pebble-gravel is far less frequent, and its position there does not indicate its having once spread over a continuous plain; but it presents itself occasionally beneath the Glacial Clay, between the elevated outliers of the Bagshot Sand, around which the Glacial Clay has been bedded, as is shown in the accompanying section, at Theydon Mount and Stapleford Tawney; and it is here again almost exclusively composed of pebbles derived from the pebble-beds first described and marked 4 in the section, partly unbroken, and partly broken into fragments of various sizes, fragments both of quartz and quartzite being rare. In neither of the directions, therefore, in which these " higher plain gravels " are to be traced southward from the area described by Mr. Hughes do we find that large admixture of quartz in them which he considers to prevail over the area embraced in his paper. Moreover both the quartz and quartzite-pebbles are extremely abundant in the Middle Glacial Gravel, where that formation comes out from beneath the Glacial Clay further to the east, at Writtle near Chelmsford.

The Gravel which caps Shooters Hill in Kent, if it be not of Post-Glacial age, may probably belong to the bed No. 6.

The view taken by Mr. Hughes, that this pebble-gravel belongs to a period anterior to the gravel of the lower plain, is of more general importance than at first sight appears, since, according to my view of the distinction of the beds, it involves the admission that there has been a period intermediate between that of the pebble-beds marked 4 in the section and the Glacial, during which the sea occupied these counties, and deposited the Gravels of the Higher Plain. That view seems based principally upon the composition of the gravel in question where it occurs in Herts; but when its composition further south and south-east is considered, with its position relatively to the pebble-beds No. 4 capping the Bagshot outliers, its age appears to me to be intermediate between the Middle Glacial Gravel (No. 5) and the Glacial Clay that overlies the two gravels alike, its accumulation in these parts having been due to the destruction of the pebble-beds marked 4, which formed the shore during the interval which elapsed between the setting in of the submergence which closed the Middle Glacial formation and the disappearance of the highest elevations, crowned with bed No. 4, beneath the sea of the Upper Glacial Clay.

It may be fairly objected, as was done upon the reading of this

* Proceedings, vol. ii. p. 181.

paper, that if the bed No. 6 be of an age intermediate between Nos. 5 & 7, it should occur between the two latter where they are in superposition. The bed No. 6, however, is of such limited and exceptional occurrence, and is due, as I regard it, so entirely to the contiguity, in the particular parts of its occurrence, either of the pebble-beds beneath the London Clay, or of bed No. 4, that its existence in any form sufficiently marked to be detected over bed No. 5 is scarcely to be expected. But, in truth, the bed No. 6 is sometimes, as at Bencroft Wood, only one mile from the termination of Mr. Hughes's section, so completely undistinguishable in general appearance from that usually presented by bed No. 5, that I felt constrained, notwithstanding its much higher elevation, to delineate it in the survey-map made by me, which I had the honour to place in the library of the Society, under the same colour and symbol as the bed No. 5, and confine myself to calling attention in the Memoir which accompanied it to the difference of level which existed between them.

The relative levels of the beds in this part of Essex are shown (as nearly as the absence of any figures denoting the precise elevations on the Ordnance Maps enables me to show them), in the accompanying section, which extends from the termination of that given by Mr. Hughes for twenty-two miles south-eastwards to the brow of the Thames valley. The elevation of what is clearly the same bed as No. 6 at Finchley, as also of the patches at Totteridge, Barnet, and other summits in Middlesex, that seem to belong to it, *relatively* to the Bagshot of Hampstead are, I think, very similar, although the *absolute* elevation of Hampstead Heath, and of these pebble-capped summits of Middlesex, is probably some 50 feet or more higher than those of Essex shown in the section.

The patches of this High-Plain Gravel that stretch northwards towards the centre of Herts have not, I think, any considerable extension, and not any such as would, I submit, point to a submergence of this part beneath the sea prior to the Middle and Upper Glacial deposits*. It appears to me that they have been accumulated under the same physical conditions, and at the same time as those that stretch southwards towards the Bagshot outliers, except that, in lieu of the flint-pebbles having in the former area come from the bed No. 4, they may have been derived from outliers of the Lower London Tertiaries, which, owing to the rise of the Lower Tertiaries towards Herts, were scattered over the higher plain in that part at the time when it began to subside beneath the Glacial sea.

DISCUSSION.

Mr. PRESTWICH was inclined to regard some of the beds referred

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* There are some quartzose pebble-gravels at high elevations in Oxfordshire noticed in the Memoirs of the Geological Survey (Memoir for sheet 13, p. 55; see also 'Geology of the Country round Woodstock,' p. 27); but any connexion between them and the bed now under discussion would be difficult to trace. Their relation to the Glacial Clay does not appear.

by the auther to the Bagshot series rather as local drifts derived mainly from those beds than as the beds themselves.

Mr. WHITAKER saw a difficulty in classing the pebble-beds at Brentwood and elsewhere among the Bagshot beds, as in the London district, at all events, no such pebble-beds occur in the Bagshot series.

Mr. EVANS pointed out the extreme improbability of the gravels at the high level having been deposited at a later period than those of the low level, without, at the same time, overlying the latter.

Mr. SEARLES WOOD considered that there was not that broad line of distinction to be drawn between the gravels of the higher and lower level; he maintained that the pebble-beds referred by him to the Bagshot series, when truly *in situ*, were free from Quartzite.

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3. *On the* LOWER CRETACEOUS BEDS *of the* BAS-BOULONNAIS, *with notes on their* ENGLISH EQUIVALENTS. By WILLIAM TOPLEY, Esq., F.G.S., of the Geological Survey of England and Wales.

(Abridged.)

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I. General description of the district.
II. Description of the beds.
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    2. Junction beds.
    3. Lower Greensand.
    4. Neocomian (?).
    5. Wealden.
    6. Purbeck.
III. Conclusion.

THE following notes are the result of an excursion made, with my colleague Mr. Whitaker, in the summer of 1866, supplemented by two hasty visits by myself later in the same year.

To Mr. Whitaker and to M. E. Rigaux, of Boulogne, I am indebted for much assistance.

I. GENERAL DESCRIPTION OF THE DISTRICT.

The Bas-Boulonnais forms the easterly continuation of the English Wealden area, both being bounded alike by a well-defined escarpment of Chalk. The lowest beds exposed in the Weald have been doubtfully referred to the Purbeck formation; but none of undoubted precretaceous age occur therein on the English side of the Channel.

In the Bas Boulonnais the major part of the surface is occupied by Lower Secondary and Palæozoic beds, the Lower Cretaceous rocks occupying only a narrow border at the foot of the Chalk escarpment, and capping the hills in the interior. The Chalk falls away from the escarpment with a gentle slope. The Gault generally occupies a slight depression at the base of the Chalk hills; but, from its diminished thickness, the valley thus formed is far less striking than

in Kent. The Lower Greensand is too thin to make a constant
feature in the district ; towards the south and south-east, however, it,
together with the underlying ferruginous sands, forms the range of
hills which runs more or less parallel with the Chalk, but without
making a well defined escarpment. The hills of the central district,
which are capped by ferruginous sands (Wealden), are mostly
barren.

II. Description of the Beds.

1. *Upper Greensand and Gault.*—These beds differ but little from
those seen on the Kentish coast, and have been so often described
that I will only note the section exposed (in June 1866) in the new
railway-cutting at Caffiers.

> Chalk-marl.
> Chalk-marl, with green grains, sandy and con- ⎫ 2 to 3 feet.
>   taining nodules in the lower part .... ⎭
> Greensand with phosphatic nodules passing ⎫ 4 to 6 inches.
>   into very green clayey sand .... ⎭
> Blue Clay (Gault).

The Gault is much thinner in the Boulonnais than in Kent, probably
not more than 50 feet at Wissant. It has the same character in
both places, and does not need detailed description.

2. *Junction Beds.*—The layer of phosphatic nodules so characteristic
of the base of the Gault in the south-east of England is also equally
well shown in the Boulonnais.

At Copt Point this bed is very well seen along the cliff below the
dark Gault clay. It is about 1 foot thick, mostly composed of
phosphatic nodules and pyrites in a state of decomposition when
exposed to the air. Wood bored by mollusks is also common. The
fossils found in this bed are seldom entire, often in casts, and *all
phosphatic.* Below this comes loose quartzose sands, also containing
phosphatic nodules and fossils. This sand is of varying thickness ;
it rests upon, and sometimes passes into, a rather coarse, hard, cal-
careous sandstone.

This account will exactly describe the junction at Wissant cliffs.
The phosphatic bed containing much wood may here be very well seen
under the Gault, and overlying the calcareous sandstone, which stands
out in rocks at low water.

Fig. 1.—*Section in Railway-cutting west of Caffiers.*

a. Angular flint-gravel
b. Blue clay (Gault)

At Caffiers cutting the junction was very distinctly seen, and gave
the above section (see fig. 1).

		ft.	in.
c.	Layer of phosphatic nodules and fossils................	1	0
d.	Very green sand	2	0
e.	Layer of phosphatic nodules	0	1
f.	Greenish rather clayey sand	2	0
g.	Light greenish and grey sand, reddish below	3	0
h.	Lignite, not constant	0	2
i.	Greenish sand, resting unconformably on..............	2	0
k.	Highly inclined shales (Devonian).		

The junction between the Gault and the Lower Greensand is usually taken at the base of the phosphatic bed; and it is generally understood that there is a sharp lithological and palæontological break between these two divisions. That they are well marked off from each other on the large scale, in the south-east of England, is certainly true; but a careful examination of the junction will frequently show that there is a very decided *passage* from one to the other.

Fig. 2.—*Section through Caffiers* (about 5 miles).
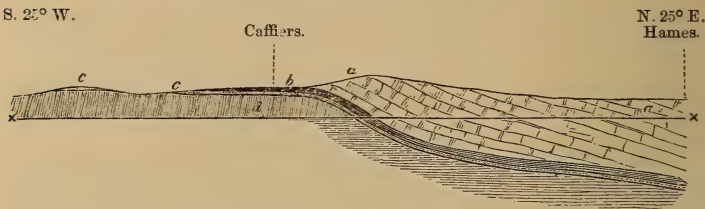
a. Chalk and Upper Greensand. b. Gault. c. Lower Greensand.
d. Palæozoic. × ×. Sea-level.

The phosphatic bed at Copt Point belongs evidently to the Gault; its fossils clearly place it there. But in the sands below are found phosphatic nodules with Gault-like fossils (also phosphatic), which, therefore, should also be referred to the Gault. *Ammonites mammillaris*, Schloth., *A. Beudantii*, Brong., and *Inoceramus Salomoni*, D'Orb., are very common in these sands and in the coarse calcareous grit below. M. Gaudry * has noticed the occurrence of *A. mammillaris*, in the sands at Folkestone and Wissant; he proposes to separate them from the Lower Greensand and to place them with the Gault.

The lithological passage is not less evident in some places: at Copt Point, where there is only one line of phosphatic nodules, it is not difficult to fix upon a boundary between the two beds; at Wissant, it is not so definite, still less so at Caffiers; and where there are two or more well-marked layers of nodules it is difficult to decide at what point to take the junction. A section open about three years since at the west end of the Lees, Folkestone, showed three beds of nodules, the overlying clay being true Gault, and the intermediate beds in descending getting more sandy; the sand below the third bed of nodules belonged to the true Folkestone beds, and contained a small nest of nodules in one place. The two upper beds of nodules contained bored wood.

* Bull. Soc. Géol. de France, sér. 2. vol. xvii. 1860, p. 32.

With regard to the palæontological passage noticed above, it must be remarked that we have here fossils of a higher bed passing downwards into a lower bed; they cannot, therefore, have been washed from one to the other, as might have been the case if Lower Greensand fossils were found passing up into the Gault. The general fragmentary state of these fossils, at first sight, gives one the impression that they really were derived from other beds. It is rare to find one entire, and they generally have a corroded appearance. This is probably due to chemical action since their deposition.

Prof. Way, who has made numerous analyses of the phosphatic bodies from the Cretaceous beds, says, " that the phosphate of lime has penetrated the various fossils and nodules *from without*, there scarcely exists the smallest question " [*].

3. *Lower Greensand.*—The masses of coarse sandstone which are seen passing under the Gault at Wissant exactly correspond to the upper part of the Folkestone Beds at Copt Point; and there can be no doubt of their representing the true Lower Greensand. In general composition these blocks resemble those at Folkestone, but are finer-grained, and appear to be somewhat richer in lime; some of them resemble coarse Kentish Rag.

The Lower Greensand, at Caffiers, has already been noticed. It probably extends all round the Boulonnais, excepting near Blacourt, where Mr. Godwin-Austin [†] has observed the Gault resting on

Fig. 3.—*Section half a mile east of Desvres* (about 4 miles).

N. 30° W.
Riv. Liane.   Haute Forêt.   Mont Hulin.   S. 30° E.

a. Chalk and Upper Greensand.   b. Gault.   c. Lower Greensand.
d. Wealden.   e. Oolites.   × ×. Sea-level.
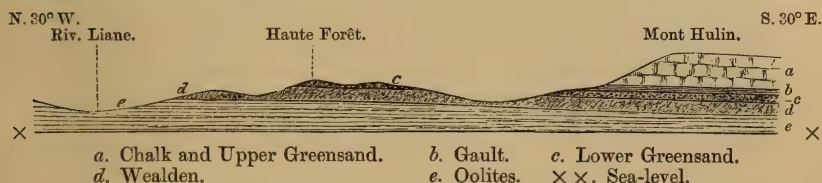
Palæozoic limestone. North of the Bois de Fiennes I saw, overlying limestone, 12 feet of greenish and greyish sand, probably almost its whole thickness here. The sand contains wood and scattered phosphatic nodules. Here, as at Caffiers, the Wealden beds are absent. At Desvres the Lower Greensand occupies the higher parts of the Haute Forêt, overlying the Weald (see fig. 3). Immediately behind the town, and to the north of it, is a pit showing 10 feet of false-bedded whitish sand, underlain by ferruginous clayey sand, which holds water and is probably Wealden.

4. *Neocomian Beds at Wissant.*—M. Gaudry, in 1859 [‡], and M. Lehon, in 1863 [§], described a dark clay in the Wissant cliffs containing *Ostrea Leymerii*. It is said to dip 35° (from the vertical)

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[*] Journ. Roy. Agric. Soc. 1st ser. vol. ix. p. 84.
[†] Quart. Journ. Geol. Soc. vol. xii. 1856, p. 68.
[‡] Bull. Soc. Géol. de France, sér. 2. tome xvii. p. 30.
[§] *Ibid.* tome xxi. p. 14.

to the south-east. (The Gault dips very gently to the north or north-east.) I was not fortunate enough to make out this bed with its fossils, and could see nothing that might not be slipped Gault. There seemed to me no beds exposed below the green sandstone. *Ostrea Leymerii*, however, is a very characteristic shell of the Atherfield beds in England, and is not known to occur in the Gault or in the higher members of the Lower Greensand.

5. *Wealden.*—The beds which I take to represent our English Wealden underlie undoubted Cretaceous rocks around most of the border of the district, and cap the hills in the interior. They are not seen on the coast at Wissant; and coming inland there is at first some difficulty in tracing the beds, in consequence of the blown sand. Near Marquise, and on the north side of the road to Wissant, is a sand-pit showing 10 feet of alternations of yellow, white, and buff sand, well bedded, with lines of darker ferruginous sands and carbonaceous beds. There are in this section a great many small faults (from 1 to 6 inches); and the pit seems to have been sunk in a small synclinal, as the beds dip down on each side.

East of the Calais road are some very interesting sections of Wealden beds resting on Carboniferous Limestone. At Bois Sergent they have been briefly noticed by Mr. Godwin-Austen *, who describes them as "thick accumulations of gravel, sand, brick-earth, and pipe-clay, with much vegetable matter, which have to be worked through for the iron-ore beneath." I have little doubt that these masses are mostly "piped" into the limestone, as is evident in a quarry a little way south-west of the houses (Bois Sergent). Here sand, clayey sand, and ferruginous sandstone are seen, clearly let down by the dissolving away of the limestone. A large pit, just north of the houses, shows a considerable thickness of the same beds, with large masses of limestone standing up below. Just west of the cross-roads (west of Bois Sergent) a large pit showed a clearly cut section of Wealden on one side and on the other large masses of limestone. The Wealden beds were very irregular in position, and not constant in character, giving in all probability a thickness of about 50 feet in these pits. The lowest part showed:—

> Yellow and white sand, from 10 to 15 feet.
> Mottled clay, 10 feet.
> Ironstone, 5 feet.

Above the sand came more mottled clay; but I could not trace any definite order here.

North of Bois Sergent there are a great number of shafts about 50 or 60 feet deep, by means of which the ironstone is raised. One of them showed in its upper part about 10 feet of brightly coloured clay (yellow, red, purple, and variously mottled); from another I got masses of blackish clay, with vegetable matter; but, as I just observed, it seems impossible to determine any definite order of succession for these clays and sands; most of the ironstone, however, came from the bottom.

* Quart. Journ. Geol. Soc. vol. ix. 1853, p. 232.

In the neighbourhood of Ferques, M. Delanoüe has described these beds *. I quote the following from his paper. The ironstones raised here are, he says, " sometimes superficial, and therefore hydrated ores, peroxidized and concretionary, with mottled clays and sands, ... and sometimes carbonates and sulphide of iron in the midst of bituminous clays. Wherever atmospheric influence has made itself felt, in former times or now, the sulphuric and carbonic acids have been replaced by oxygen and water."

In several cuttings of the new railway from Boulogne to Calais, Wealden beds are seen lying irregularly on the Palæozoic beds, and mostly let into the limestone in deep pipes (see fig. 4). Some of

Fig. 4.—*Sketch-section of Railway-cuttings near Elinghen.*

S.W.   Haut Banc Quarries.   Elinghen Church.   N.E.

a, a, a. Carboniferous Limestone.   c. Angular Flint-Gravel.
b, b, b. Wealden Sands and Clays in pipes.   × ×. Level of Railway.
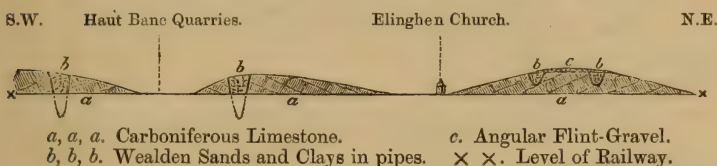
them are of large size : in one a depth of 30 feet was seen ; and as this was 20 feet wide at the bottom of the cutting, it must descend considerably deeper. These pipes contain sand, brown and variously coloured clays, ironstone, and pipe-clay, with vegetable remains. The patch at Elinghen is, as shown by pits, like that in the railway-cuttings. Although the Wealden beds have a fair thickness around Elinghen, yet a mile or so to the north-east, at Caffiers-cutting, there are none, Lower Greensand here resting immediately upon Palæozoic beds ; and the Greensand itself is reduced to a thickness of a few feet. The same is the case in a road-cutting west of the Bois de Fiennes. The section here, already noticed, is less than a mile from Elinghen.

The high ground north-east of Bournouville is occupied by Wealden beds. What little is shown here is mostly sand and a loose conglomerate of quartz pebbles, partly cemented by iron. Some pits show small pebbles with a whitish sandy clay, roughly bedded.

Near Desvres, in the Haute Forêt, is a large pit in Wealden beds, showing from above downwards :—

        1. Clay and loamy wash.
        2. Brown and whitish clay.
        3. Blue clay.
        4. Blue sandy clay (with lignite).
        5. Ironstone.

The beds here, as usual, are very irregular. Another part of the same pit showed coarse sand and pebbles, cemented by iron into a brecciated conglomerate. These Wealden beds seem to go some way up the hill ; but towards the top is coarse sand of a lighter colour,

* Bull. Soc. Géol. France, sér. 2. tom. ix. 1852, p. 403.

with pieces of chert lying about.   This I take to be Lower Green-
sand (see fig. 3).

Samer rests on Wealden beds: light-coloured, whitish, and yellow
sand, with some pebbles and mottled clay ; and in places between
here and Desvres, sands (sometimes ferruginous) and mottled clays
are seen.

Some very interesting sections are exposed near Equihen and St.
Etienne-au-mont, three or four miles south of Boulogne.   The hill
above Equihen is capped by Wealden beds, with a slight covering
of loam and subangular flint-gravel.   The different sections here
are as various in character as elsewhere.   One pit gave :—

> Blown sand.
> Whitish sandy clay, with sandy ironstone, 6 feet.
> Hard concretionary sandstone, very ferruginous, 3 to 4 feet.
> Yellowish clay and concretionary clay-ironstone.

another section was as follows :—

> Sandy flint-gravel.
> Loose pebbles, with 1 inch of pipe-clay near the bottom, 6 to 8 feet.
> Sand and coloured clay (white, yellow, blue, and sometimes black, with
>   vegetable markings ?), 5 or 6 feet.
> Ironstone.

Near the church of St. Etienne are many sections, some of which
have been very minutely measured by MM. Sauvage and Hamy [*].
As no two pits are alike, nor any one pit regular in all its parts, I
have not attempted any such accuracy.   I give two or three examples.
Just south of the church :—

> Dirty loam and loose pebbles, to 3 feet.
> Pebbles, 6 feet.
> Bluish clayey sand, 1 to 6 inches.
> Yellow sand and sandstone, 4 feet.

A second pit further east showed a few thin layers of hard ferru-
ginous sandstone with the pebbles.

A third pit south-east of the church :—

> Interstratified sand and small pebbles false-bedded, particularly near the
>   top, 15 feet.
> Yellow and white sand.
> Green clay and ironstone.

Other pits towards the southern part of this outlier show good
sections of the pebble-beds.   In one case they are divided by five feet
of sandy clay :—

> Pebbles, 2 feet.
> Whitish sandy clay, 5 feet.
> Pebbles, 5 feet.

Around Boulogne all the heights are occupied by Wealden beds.
In the new railway-cutting at Honvault, a fault brings Wealden

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[*] Terr. Quatern. des Boulonnais, p. 7 ; see also Rigaux, " Notice Stratigra-
phique sur le Bas-Boulonnais," Bull. Soc. Académique de Boulogne, 1865.

against Portland limestone, the latter rising from beneath the Wealden at the north end of the cutting.

Capping Mont Lambert there is ferruginous sandstone with large pebbles. I presume this likewise is Wealden, but could find no clear section. The hills north and north-west of this are capped by Wealden beds, which are in many places worked for ironstone. The sections at Rupembert are of interest, as the ironstone there contains casts of fossils (*Cyrenæ*).

Where, as in the neighbourhood of Boulogne, the Wealden beds rest on Portland, it is difficult, in some cases, to divide them, as the following section from a quarry north of Napoleon's Column will show :—

1. Sand, and clayey sand, 4 feet.
2. Bluish and mould clay, 4 to 6 feet.
3. Irregular beds of sandstone and ironstone, 1 to 2 feet.
4. Clay, bluish above, yellowish below, with lignites at the bottom, about 6 feet.
5. Sandstones, soft above, hard below, 4 feet.
6. Greenish sand, 1 foot.
7. Hard sandstone, with veins of carbonate of lime, 4 feet.

The upper beds here are certainly Wealden, and the lower certainly Portland. Perhaps 1, 2, 3 belong to the former, 5, 6, 7 to the latter, and 4 to a bed of doubtful character to be further mentioned presently (see p. 481).

Wealden beds are seen here and there along the coast north of Boulogne, and everywhere on the inland heights ; but the sections given above may suffice to show their general character.

French geologists have long been in doubt as to the exact age of these beds. By many they have been classed with the Lower Greensand (Rozet, d'Archiac, Delanoue, and Fitton in 1826). Gosselet and Hébert would place them with the Gault, whilst Sauvage and Hamy have described some outlying patches as Drift. By Conybeare in 1822[*], Fitton in 1839, and since then by Rigaux and Pellat, these beds have been referred to the Wealden.

In the loose pebble-beds at St. Etienne, which I have described, are some fragments very like flints, and others greatly resembling chalk ; from this circumstance Messrs. Sauvage and Hamy have been led to class these with the Drift. Such chalky-looking pebbles are very common in the conglomerates at the western part of the Weald, near Cuckfield and Lindfield ; they are probably derived from the waste of Portland beds. At Cuckfield these conglomerates form part of Dr. Mantell's Tilgate beds, and contain the usual reptilian remains. So much do some of the pebbles resemble chalk that Dr. Mantell, in 1822[†], described these beds as " diluvium." In subsequent descriptions of the district he omitted any mention of chalk pebbles, and included the beds in question in the Wealden formation. There can

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[*] 'Outlines,' p. 155. The Hastings sands were then called " Iron Sands," and their freshwater origin was not then recognized. This brief reference by Mr. Conybeare to the Boulonnais ferruginous sands is the earliest geological notice I have been able to find. It is interesting to note that his supposition as to their age is the correct one.

[†] Fossils of the South Downs, p. 39.

be no doubt of the correctness of Dr. Mantell's later conclusion, as clays and shales of the Wealden series are frequently found overlying such conglomerates.   The occurrence of flint-like pebbles at Piche-vert, near Marquise, led Dr. Fitton to think the beds there were of comparatively recent date, derived from the waste of Wealden beds, but intermixed with flints from the chalk.   The mode of occurrence of these pebble-beds in the Boulonnais is such as is very likely to mis-lead an observer as to their true age, particularly if unacquainted with the details of our English Wealden beds.   They are mostly found capping the hills, and are not overlain by other beds; at Desvres, however, I noticed pebbles cemented into a conglomerate; here the section is low down the hill, and the whole series is capped by Lower Greensand.   At Samer, also, pebbles occur in the Wealden beds.

Very few fossils occur in the Wealden beds of the Boulonnais. Dr. Fitton mentions *Melanopsis* or *Paludina* from near Wimereux, associated with a shell resembling *Astarte*.   The fossils may have come from the ferruginous sands; but neither their identification nor mode of occurrence seems very certain.   M. Rigaux mentions *Unio* from Equihen and *Cyclas* or *Cyrena* from Rupembert.   To this last locality I was obligingly taken by M. Rigaux; the fossils are very plentiful in the ironstone, but occur mostly as casts, which Pro-fessor Morris believes to be those of *Cyrenæ*.   M. Pellat has also found *Cyrena* at Equihen.

The Wealden ironstone of the Boulonnais is largely worked for smelting, over the central and south-eastern district mostly by open quarries, in the north chiefly by shafts.   There are large blast-furnaces at Marquise, and at Outreau, near Boulogne.   At Marquise, according to M. S. Jordan [*], the ironstone is mixed with ore from Africa, chalk and other limestones of the district being used for flux; at Outreau the native ore is mixed with Cumberland hæmatite.   An analysis of Boulonnais Wealden ore gave 49·14 per cent. of peroxide [†] (=34·39 per cent. of iron).   Some account of the smelting of this ore and of comparisons with other works in the north of France is given in a paper by M. Leducq, read at the Society of Agriculture of Boulogne in 1834 [‡].   These furnaces are all of recent origin; no mention is made in Rozet's Memoir (1828) of the ore being worked, nor in Bertrand's 'Histoire de Boulogne' (1829).   M. Henry, in 1804 [§], alluding to the great quantity of iron-ore in the district, stated that the only obstacle to smelting it was want of fuel. Coke is now chiefly got from Belgian coal.

The iron-ores of our English Wealden have been worked from the Roman times downwards.   In the 17th century this was the chief iron-producing district of England; for out of 800 " milnes for the

* Cuyper's 'Revue de l'Exposition Universelle de 1867,' p. 416.
† *Ibid.* p. 414.
‡ 'Du Développement de la Production du Fer dans le Nord-ouest de la France, Procès Verbal,' p. 183.   8vo, 1835.
§ 'Essai historique . . . sur . . . Boulogne-sur-mer.'   4to, p. 225.   (Printed 1804, published 1810.)

making of iron" in England and Wales 400 were in Surrey, Kent, and Sussex *. The fuel was wood charcoal, which becoming scarce, and at the same time pit-coal coming into use elsewhere, the trade gradually declined; only nineteen furnaces and forges are marked in Bugden's map of Sussex (1724), whilst at the end of the last century there were only two. The last furnace, at Ashburnham, lingered on till the middle of the present century.

6. *Purbeck.*—Immediately overlying the Portland beds on the cliffs north of Boulogne are some thin beds which have been described as Purbeck. I was not able to make out these clearly, and shall therefore only briefly refer to what others have written concerning them.

Dr. Fitton first pointed them out, in 1826†—and again in 1836‡, when he described "a thin crust of Purbeck strata, resting upon those of Portland, and consisting of slaty beds of limestone, which contain freshwater shells, and include a bed of tough dark-coloured clay, in which are numerous fragments of silicified coniferous trunks, not distinguishable from those of the Dale of Portland." Fitton, in 1839§, further refers to this bed, and mentions that the silicified wood is not found in place, but lies loose on the surface. It is probably the same as that which Desmars, long before, described as " bois fossiles " ‖. Dr. Fitton says that *Cypris, Cyclas,* and *Ampullaria* (?) occur in this bed. Rozet¶ mentions a bituminous clay as underlying the ferruginous sand in places. This may sometimes be the base of the Wealden, but I have observed a very tough dark-coloured clay in the Forêt de Boulogne and south of Bernes: in both cases Wealden sands rest on Oolitic limestone; and I am inclined to think the clay is only the result of carbonated water percolating through the sands and dissolving the limestone.

Further observations upon the supposed Purbeck beds of the coast will be found in late papers by Pellat and Hébert **.

III. CONCLUSION.

A comparison of the Cretaceous beds of the Boulonnais with those of Kent shows a striking diminution in thickness from west to east (see fig. 5)††. This alteration is seen in all the beds, but in some more than others, while a few disappear altogether. It is seen very markedly in the Lower Greensand; the Folkestone beds are much reduced in thickness, whilst the Sandgate and Hythe beds are gone altogether. According to some observers the Atherfield Clay is represented at Wissant; but it is certainly not constant round the district.

* Sturtevant's 'Metallica,' 4to, 1612, p. 5. (Reprinted at Wolverhampton, 1855.)
† Proc. Geol. Soc. vol. i. p. 9.   ‡ Trans. Geol. Soc. ser. 2. vol. iv. p. 326.
§ Bull. Soc. Géol. de France, sér. 1. vol. x. p. 440.
‖ De l'air, de la terre, et des eaux de Boulogne-sur-mer, ed. 1761, p. 7.
¶ Desc. Géognostique du Bas-Boulonnais, 1828, p. 48.
** Bull. Soc. Géol. sér. 2. vol. xxiii.
†† As this paper refers only to the Bas-Boulonnais, I have made no remarks upon the chalk of the bordering escarpment and the Haut-Boulonnais. Mr. Phillips has shown that the various beds into which he divides the chalk of south-east Kent are much reduced in thickness in the cliffs between Wissant and Sangatte. (Trans. Geol. Soc. ser. 1. vol. v. p. 48.)

Perhaps the most striking variation is exhibited in the Wealden beds, which, from a total thickness of 1200 or 1500 feet on the Kent and Sussex coast, have dwindled away in the Boulonnais to 100 feet or less.   On the English coast the great division between Hastings

Fig. 5.—*Comparative Sections of Cretaceous Beds in Kent and the Bas-Boulonnais.*

South-east of Kent.   Bas-Boulonnais.

Chalk ....

Upper Greensand.   Chalk.

Gault ....   × *Sandy Bed*   Upper Greensand.
                                                    Gault.
                                                    Lower Greensand.
                                                    Wealden.

Folkestone Beds....

Sandgate Beds......

Hythe Beds ....   / Molluskite in places.

Atherfield Clay......

Weald Clay ....

Lower Greensand.

× × Show horizons at which Phosphate of Lime is found.

                              100   200
Vertical scale | ı   ı   ı | feet.
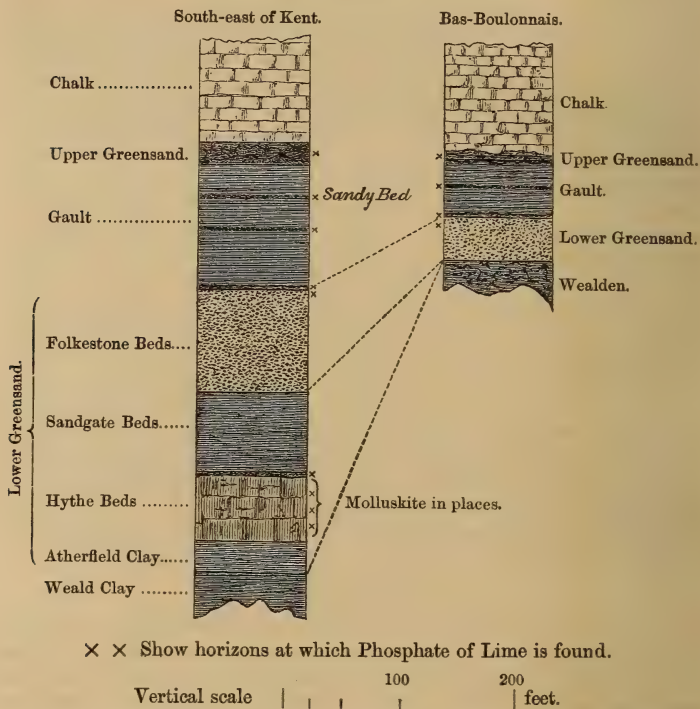
Sand and Weald Clay is very marked, as also are the subordinate divisions of the Hastings Sands; but it is impossible to say what part of our English series the Boulonnais beds represent.   In the quantity of mottled clays they resemble the Ashburnham beds, as seen in the cliffs east of Hastings; but such mottled clays are not confined to any horizon in our Wealden beds.   In the presence of quantities of pebbles, some coarse and containing chalk-like fragments, they resemble the top of the Hastings sands near Cuckfield; but similar conglomerates occur elsewhere and in other positions. The absence, so far as is yet known, of Saurian remains, and the comparative rarity of other fossils in the Boulonnais Wealden is a notable distinction from the English beds.

The constancy of the phosphatic bed at the base of the Gault is worthy of note.   It appears to be everywhere present around the

Fig. 6.—*Diagrammatic Section through the North of the Bas-Boulonnais.*

N. & N.E. Calais.

Marquise.   Bois Sergent.   Caffiers.   Biacourt.

S. & S.W. Boulogne.

a. Chalk.   *b.* Upper Greensand.   *c.* Gault.   *d.* Lower Greensand.   *e.* Wealden beds.   *f.* Portland beds.   *g.* Kimmeridge Clay.   *h.* Oxford Clay.   *i.* Great Oolite.   *k.* Palæozoic.
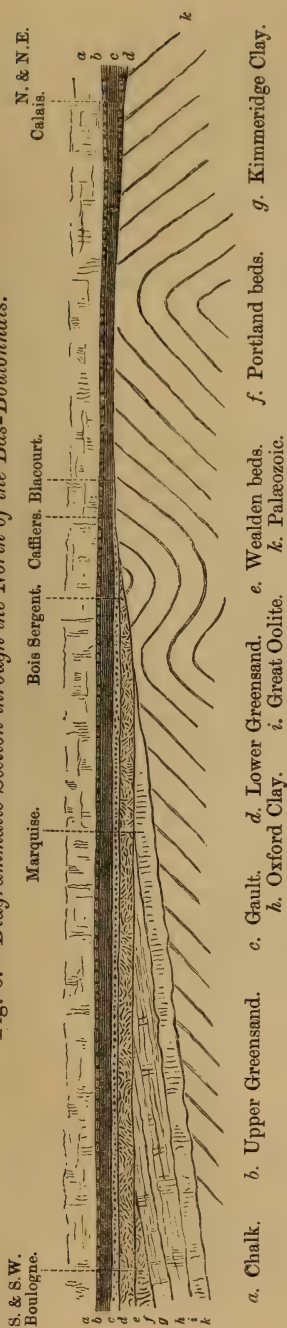
Weald, and I have always on searching found it in the Boulonnais.

In the foregoing paper the unconformity of the Cretaceous beds to all below them has been illustrated in many ways. Mr. Hopkins and Mr. Godwin-Austen have already so fully described this fact to the Society that I will only, in conclusion, call attention to the accompanying diagram, in which the chief facts are represented, viz., 1st, the unconformity of the Oolitic beds to the Palæozoic rocks; 2nd, the unconformity of the Cretaceous beds to the Oolites, the Wealden resting on all in succession until they thin away against the Palæozoic rocks; and, finally, the complete conformity that appears between all the represented members of the Cretaceous group, although some are absent.

DISCUSSION.

Sir RODERICK MURCHISON, without doubting the correctness of the author's views, wished that fossil evidence had been forthcoming to identify more conclusively the Wealden strata of the Boulonnais with those of England, and suggested their correlation with the Beauvais beds.

The Rev. Mr. WILTSHIRE remarked that in Kent the *Ammonites mammillaris* was contained in large nodules, and occurred only below the lower phosphatic band.

Mr. WHITAKER, who had been with the author in the Boulonnais, had been, contrary to his predilections, compelled to regard the beds referred to the Wealden as belonging to that formation, and not to the Lower Greensand.

4. NOTE on the MENDIP ANTICLINAL. By C. H. WESTON, Esq., F.G.S.

<div align="center">JUNE 17, 1868.</div>

Charles Baron Clarke, Esq., F.L.S., Fellow of Queen's College, Cambridge, Barrister-at-law, Dacca, Hindoostan ; and Flaxman Charles John Spurrell, Esq., Belvedere, S.E., were elected Fellows.

The following communications were read :—

1. *On the* DISTRIBUTION *of* STONE IMPLEMENTS *in* SOUTHERN INDIA. By R. BRUCE FOOTE, Esq., F.G.S., of the Geological Survey of India.

THE circumstances under which chipped implements, similar in form to those occurring in the gravels of Western Europe, are found over a considerable part of Southern India * are very interesting, as they appear to prove that great changes in the physical geography of the Indian peninsula have taken place since the time when the implement-makers first inhabited the country.

By far the greatest number of the chipped-stone implements have been found in close connexion with the laterite deposits of the eastern coast. Many implements were found *in situ*, buried in the laterite ; and many more lay scattered over the surface of the laterite, from which they had evidently been weathered out. A considerable number also were collected off the surface of underlying older rocks, in places where laterite deposits had once existed, but had subsequently been almost entirely removed by denudation, and had often left but faint traces, in the shape of scattered débris. Other implements, again, have been discovered on the surface in other parts of the country, where no distinct traces could be seen of the formations from which they might have been weathered out. Whatever may have been the nature of these latter deposits, the great elevation at which they occur above the lower country precludes, in the absence of any evidence to the contrary, the idea that they were of the same marine origin as the coast laterite.

It is not at all improbable that they may once have been enveloped in freshwater deposits which have since been destroyed by denuding agencies, while only the heaviest included bodies, such as the coarse shingle and implements, were left behind as evidences of the former existence of such formations.

Besides the above, a few implements have also been found in unquestionably fluviatile formations ; but none have been obtained from any deposits known to be more ancient than the laterite, nor have the *younger* alluvia, whether marine or fluviatile, yielded any that could not be shown to have been washed down from immediately adjoining lateritic beds.

The position occupied by the laterite along the coast is that of a belt running parallel with the general coast-line, but broken through

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* For an account of the discovery of these implements see the ' Proceedings of the Asiatic Society of Bengal,' 1844, p. 67 ; also ' Madras Journal of Literature and Science,' October 1866 (third series, pt. 2) :—" On the occurrence of Stone implements in Lateritic formations in various parts of the Madras and North Arcot Districts," by R. Bruce Foote, Geological Survey of India, with notes by William King, jun., B.A., Geological Survey of India.
Some copies of this paper were struck off and circulated in June 1865.

Fig. 1.—*Diagram Map showing the area which would be submerged by a depression of 500 feet*

1. Naggery Mountain.
2. Sattavedu Hills.
3. Alicoor Hills.
4. Kircumbadi.
5. Naikenpolliam.

R. B. Foote, 1869

at many points by the different rivers falling into the Bay of Bengal.

This belt has been examined and surveyed by my colleagues, Messrs. Blanford, Charles Oldham, King, and myself, from the neighbourhood of Tanjore northward, very nearly up to Ongole, a distance of upwards of 300 miles.

To the southward of Tanjore the laterite is said to extend over great part of the Tondiman Rajah's country, and, with interruptions, nearly down to Cape Comorin; but it has not been examined by any members of the Geological Survey of India for more than 10 miles south of Tanjore. To the north of Ongole it will no doubt be found again, occurring in patches along the coast, until it joins the laterite of Orissa, so well described by Mr. William T. Blanford in the 'Memoirs of the Geological Survey of India' *.

The width of the belt of laterite varies considerably, but rarely exceeds from 8 to 10 miles; in very many places, however, small outlying patches, a few acres, or sometimes only a few square yards in extent, occur at considerable distances to the westward, showing how much has been removed by denudation. The seaward or eastern margin of the belt has generally a well-defined edge; indeed it frequently terminates in a low but abrupt scarp.

The western boundary, on the contrary, is often very ragged, the deposit having thinned very much, and its continuity having been so much broken by denudation that it often becomes impossible to separate it from the highly ferruginous red soil of the country, this red soil being itself in very many places nothing but reformed lateritic débris.

No organic remains having as yet been found in the lateritic formations, some fragments of silicified wood excepted, the only thing to guide us in determining their origin is their position, which is that of a great fringe along the eastern flanks of the high land. This is quite analogous to the geographical position of the underlying Jurassic, Cretaceous, and Postcretaceous rocks, all of which are of unquestionably marine origin. This analogy of position holds good also with reference to the recent coast-alluvium, and is, it appears to me, fully sufficient to justify the conclusion that the lateritic formations were deposited along the shore of a moderately shallow sea.

The typical laterite † is a red ferruginous clay, more or less sandy, and often containing nests of white, yellow, and pink lithomarge and clay, but enclosing, as a rule, no other substances; near Madras, however, the laterite, though maintaining these characters to some extent, often includes numerous pebbles of quartzite, with a few of quartz and gneiss, and becomes a regular conglomerate, in which occur the chipped implements. In some parts of the Madras district the laterite loses its clayey character to a great extent, or even altogether, and passes into coarse gravel and gravelly sands, con-

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* Vol. i. p. 280.

† The name Laterite was given by Dr. Francis Buchanan, who described the laterite of the Western Coast in his 'Journey from Madras through Mysore, Canara, and Malabar,' London, 1807, 3 vols. 4to. *Vide* vol. ii. pp. 436 & 440.

Fig. 2.—*Section from the Mysore Plateau across Naggery Mountain to the Sea (80 miles).*

W. by N.

Aoulpilly Droog.

Chittoor Terrace.

Naggery Mountain.

Alicoor Hills.

Atrampakkam Nullah.

Red Hills.

E. by S.

a. Gneiss.   *b.* Cuddapah rocks (Quartzite).   *d.* Jurassic rocks.
e. Laterite and Gravels.   *f.* Alluvium.
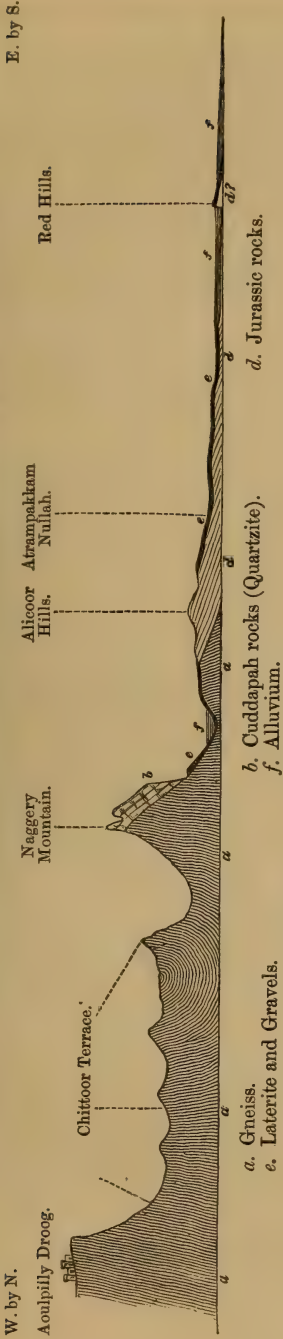
Fig. 3.—*Section from Roodvar through Pamur to Ramiapatnam (100 miles).*

W. by N.

Roodvar.

Nulla Mulla Mountains.

Vellaconda Mountains.

Byrawudi Conda.

Pamur Hill.

Goodloor.

Ramiapatnam.

E. by S.

Fault.

a. Gneiss.   *b.* Cuddapah rocks (Quartzites and Slates).   *c.* Kurnoor Series.
d. Jurassic rock.   *e.* Laterite and Gravels (marine).   *e'.* Freshwater beds with implements.
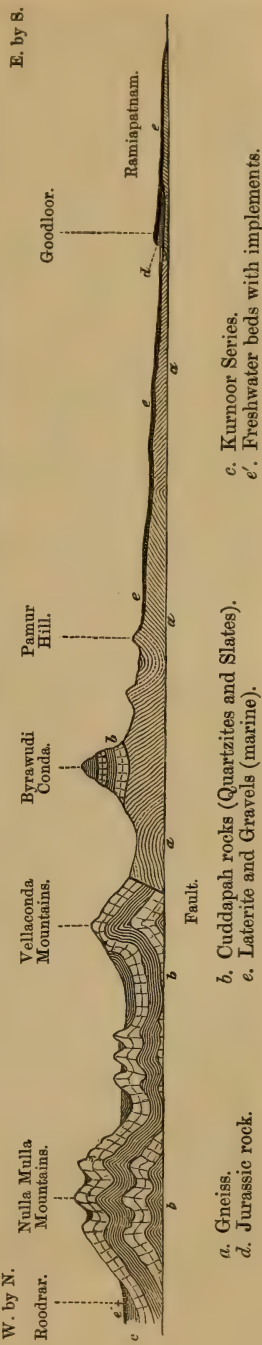
sisting mainly of quartzite with a varying proportion of impure brown hæmatite pellets.

The quartzite pebbles of the laterite can easily be traced to the sources whence they came, which are at no great distance off. The primary source of these pebbles is to be found in the immense quartzite formations capping the summits and ridges of the Naggery Mountains, a group of bold detached mountains which stand out between the eastern Ghats and the Pulicat lake.

The secondary source of the quartzite pebbles is the vast Jurassic conglomerates forming the Alicoor and Sattavedu hills, two groups of hills lying to the south and south-east of the Nagari (Naggery) mountains. These conglomerates are in part quite unsolidified, partly also compacted into hard rocks. They have yielded an abundance of already perfectly waterworn material towards the formation of the much younger lateritic conglomerates. It was from these Jurassic conglomerates also that the implement-makers drew their supplies of pebbles out of which to chip the various tools and weapons they required.

The laterite conglomerates occur chiefly around the base of these conglomerate hills, which must have stood up as islands in the laterite sea, and may very likely have been the home of the tribe of men by whom the implements were manufactured and used. The annexed diagrammatic section (fig. 2) shows the general relations of the different geological formations referred to.

The Alicoor hills formed the most southerly source whence these people could at that time obtain any quartzite; and the number of implements in the laterite decreases steadily the further you go from these hills in a southerly direction. The most southerly point at which I found implements was close to the Rajah's Choultry, $3\frac{1}{2}$ miles north-east of Coujeveram. The country south of the Palar river yielded no quartzite implements, though examined for them by my colleague, Mr. Charles A. Oldham, a very keen-sighted and close searcher. To the west and east of the Alicoor hills a similar steady diminution of the number of implements, increasing with the distance from the hills, is observable. The extent of the lateritic formations has been much diminished, on their western side, by denuding agencies; but débris of the laterite occurs scattered over the gneiss rocks for many miles to the west, and may be fairly regarded as the ruins of the laterite formation. Among this débris a number of implements were collected by myself and by several of the engineers of the Madras Railway stationed at Arconum.

To the northward of the Alicoor hills the case is different; for the supply of quartzite did not cease, the main mass of the mountainous coast being formed of quartzite beds for nearly 200 miles northward up to the banks of the Kistna river. The conglomeratic character of the laterite continues in great measure in the different parts of the belt running northward through the whole length of the Nellore district; and I collected implements at several places along this line * in

* The systematic survey of the southern half of the Nellore district was all

August 1866. Here also there are abundant evidences that the laterite extended far inland, in some parts even close up to the base of the mountains. The lateritic débris is found largely scattered over the country; and with it occur implements.

It has been already mentioned that no chipped quartzite implements have been found south of the Palar river, although laterite occurs there and far to the south. I am hopeful, however, that the implements will be traced still further south; but, doubtless, they will be found much more rarely the further we go from the sources of supply of quartzite. The laterite of Pondicherry and the patches further south have not been specially searched for implements, as they were surveyed several years before the discovery of the chipped weapons in India.

Assuming these lateritic formations along the Coromandel coast to be of truly marine origin, the question arises, To what depth below its present level was the land depressed? This question can only be solved by ascertaining the highest levels at which the lateritic deposits are found to occur. The highest elevation of the implement-bearing beds which has been accurately measured, is 370 feet above mean sea-level at Madras; this is at Kircumbaddy, on the north side of the Soornamookey valley. I am indebted for this measurement to Mr. W. R. Robinson, C. E., of the Madras Railway, a gentleman who took great interest in the discovery of the stone implements, and himself made a large collection of them from this locality.

The next highest measured elevation is that of the lateritic debris occurring on the elevated ground near the Arconum railway junction, which attains a height of upwards of 300 feet above the sea-level.

During my last visit to the Alicoor hills, in August 1865, I found several implements lying on the much-weathered surface of the laterite, a considerable distance up the slope of the hills N.N.W. of Naikenpolliam, at an elevation which I believe considerably exceeds that of the foregoing cases. Unfortunately I had no instruments with me at the time to make an exact measurement, so had to content myself with an estimate of the elevation, for which, however, the circumstances were very favourable.

At a distance of 3 miles from where I found the implements is a station of the great Trigonometrical Survey of India, marked in the map as the Nemilly hill, which has an elevation of 367 feet above sea-level. This Nemilly hill is perfectly overlooked from the spot at which I obtained the implements in question, which must, therefore, be at a considerably greater elevation, and probably lies between 500 and 600 feet above sea-level.

That the implements here found were really derived from the underlying lateritic conglomerate I have no doubt, as they were deeply stained of a purplish-brown colour, which characterizes the

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but completed by Messrs. Charles A. Oldham and William King previously to the discovery of the chipped implements near Madras in 1863.

conglomerate and its débris at this place. The implements were much waterworn and very smooth, as if they had not been long exposed to the roughening action of the atmosphere. The spot at which I found these implements lies but little below what was probably the uppermost limit of the laterite ; for on ascending further up the hill all lateritic débris is soon lost sight of, and the surface consists only of a weathered crust of the Jurassic conglomerates, which are of drab and grey colours, and in this district very free from ferruginous matter.

The other indications of the former greater extension of the laterite deposits, occurring further to the north, which have been alluded to, are met with in the northern half of the Nellore district, in the shape of lateritic débris, occurring in scattered patches over the general surface of the country, but at much higher levels than the alluvia of the existing streams, which are excluively confined to the generally deep and narrow valleys.

The first of these patches that I had the opportunity of examining lies to the south and south-east of the small town of Pamur, where a broad tongue of high ground extends eastward from the foot of the Byrawudi mountain, between the small rivers which unite to form the Munair. This elevated water-shed is covered in many places with enormously large gravel, a perfect boulder-gravel, of quartzite ; in other places the gravel is of an ordinary character ; but in both cases much ferruginous matter, in the form of pellets of clayey brown hæmatite, accompanies the gravels, on the surface of which implements were found occasionally. In all these cases the implements bore the strongest resemblance in point of stain, or possible adherence of ferruginous matter, to the patch of gravel or débris on which they occurred ; and I have no doubt that they were weathered out of the underlying gravels.

A careful examination of these gravels, which are well exposed in the sides of various deep rain-gullies of recent formations, would, I firmly believe, lead to the discovery of implements still imbedded *in situ*, and well reward any explorer. It was not in my power to give these deposits more than a very cursory examination, which I greatly regretted, as it is not unlikely that some organic remains might be found in the loamy beds which are here and there included. The gravels especially deserving of examination are those near Cumbaldinna, 8 miles E.S.E. of Pamur, and others further to the east and south-east at Ranamuddagoo and Sullawarpully. The western-most point in this region at which I found implements was at the foot of the Vaimpand hill, 6 or 7 miles south of Pamur, where a great accumulation of the boulder-gravel is piled around the hill like a talus. This gravel-bed lies at a very considerable elevation above the general level of the country, which in its turn is shown, by the long succession of rapids and falls in the rivers, to rise quickly after the flats of the sea-coast have been left behind. Comparing the level of this spot with that of the Soondy hills, which are 900 feet high, and with some of the intermediate hills, it may be safely estimated at nearly 600 feet above the sea-level. The annexed diagram section

(fig. 3) shows the relative position of the lateritic gravels just referred to.

A second area showing this peculiar lateritic gravel with implements occurs about 25 miles north-west of Pamur, near the village of Nundanawanum. The laterite sea evidently made a deep bay here, and has left considerable traces of its presence in the form of gravels and dark-red sandy clays, which extend right up to the foot of the Vellaconda Mountains. The country here at the headwaters of the Palair river is much flatter, and probably less elevated, than that around Pamar. I obtained several well-shaped implements from the surface of a gravelly clay south of the village of Ramiah-pully.

Northward of Nundanawanum I did not meet with any recognizable traces of a former presence of the laterite formations; but my visit was too cursory to enable me to satisfy myself on this point; for I expect that traces of the laterite sea will be found all over the northern part of the Nellore country, and the low country of the Kistna district up to the Kistna River.

The most northerly point at which I obtained a chipped implement was Vipur, 11 miles north of Vinukonda. It was found on the surface, but it was evidently derived from a thin spread of quartzite-gravel underlying the soil and resting on coarse syenite.

In the coast-laterite of the Nellore district the most northerly point at which I obtained implements was in the Ramiapatnam patch, the most northerly I had an opportunity of carefully examining.

At Goodloor, in the Ramiapatnam patch, I found numerous small but well-shaped implements washed out of the laterite by atmospheric denudation. With the lateritic formations now described it will, I believe, be found necessary to include the great talus-like banks of boulder-gravel occurring along the base of the Vella Condas and the Naggery mountains, which are well seen, in the case of the former, at the east end of the Dorenál Pass, and at the town of Udayaghiri. In the case of the Naggery mountains there is a splendid gravel-bank along the south flank of the Naggery Mountain itself. In this latter case I observed the quartzite boulder-shingle to be extensively stained of dark red-brown purple, which indicates that the stone had been weathered in the presence of ferruginous matter of extraneous origin, the quantity of iron, in any shape, in the quartzite being in general extremely small. This ferruginous matter I believe to have been the lateritic cement by which this shingle was partly cemented into a conglomerate precisely the same as that now seen around the flanks of the Alicoor hills. The presence of such a ferruginous cement at high levels in places where no ferruginous matter was derivable from the higher grounds, as in the case of the Alicoor hills, near Naikenpolliam, nor from the substance of the enclosed materials, may, I think, be explained by supposing that the highly agitated waters of the laterite sea carried much ferruginous matter in suspension—a supposition which is not in the least degree hazardous when we consider the immense quan-

tities of magnetic iron and highly ferruginous hornblende-rock which are now, as they must have been then, carried into the sea by every freshet in the rivers.

The highest level to which the shingle-bank is piled up, along the southern flank of the Naggery mountains, accords well with the level which I suppose to have been the uppermost limit of the laterite sea around the Alicoor hills, and which I estimate to have been rather over 500 feet above sea-level.

There remains now another set of implements to be considered, namely, those found occurring at elevations so much exceeding the above that it is most unlikely that they were ever included in deposits of marine origin, there being no evidence to justify the assumption that so great a depression of the Indian peninsula has occurred since the first appearance of the human race. The probability is that the implements found at such great elevations were preserved in local deposits of freshwater, or possibly subaërial, origin, from which they have been washed out by comparatively recent action, of rain or of running water ; for I do not think it possible they could have long resisted the tremendous weathering power of the sun, if they had been lying exposed on the surface. A considerable number of well-shaped quartzite implements were found by Mr. Charles A. Oldham and Mr. King in the southern part of the Cuddapah district, chiefly, I believe, near Rachotee, at an elevation of about 1400 feet above the sea-level,—an elevation greater by several hundred feet than the highest vertical limit I have ventured to assign to the coast-laterite. As I am unacquainted with that part of the country, and with the circumstances under which they were found, I am unable to offer any further opinion about these particular implements. There is in the Museum of Practical Geology in Jermyn Street, at the present moment, a specimen stated to have been procured from Vamimbadi, a town at the northern extremity of the Salem district, standing at an elevation of 1150 feet above the sea-level. If really derived from that place, this specimen would be further extremely interesting as having been found at a very much greater distance than any other I am acquainted with from the quartzite country.

At lesser levels than those discovered by Mr. Charles Oldham, but still from places considerably elevated over the 500 to 600-foot level of the coast-laterite, numerous implements were obtained by my colleague Mr. Wm. King, and by myself, in the Kurnool District, in the neighbourhood of Roodrar (see fig. 3). These lay on the surface of the soil, from which they had seemingly been washed out by rain-action. The soil there consists of a gravelly mixture of small globular Kunkur (or calcareous tufa-concretions) with pellets of clayey brown hæmatite, similar to those so characteristic of lateritic deposits. Black cotton-soil, or Regur, frequently covers the former soil, but has never been found to contain implements. Pebbles of quartzite are not common here, except close in to the quartzite beds of the Cuddapah group in the Nullamulla mountains.

Here, as in the case of the coast-laterite, not a single fossil shell or other organism was found to throw light on the nature of the

Kunkurry deposit; but its wide-spread extent and marl-like composition suggested to my mind the idea of its formation in fresh-water lakes rather than by extensive river-action, in a place where no large river has flowed probably for many ages past. Some few specimens were obtained by Mr. King* from what he regarded as an unquestionably fluviatile deposit; but this was at a place close to the foot of the mountains at the mouth of a large valley opening into the plains, and where the presence of river-deposits would not contravene in any way the probability of lake-deposits at lower levels further away from the high ground.

From several valleys on the eastern side of the Nullamulla mountains chipped quartzite implements were obtained from unquestionable river-gravels,—for example, the numerous implements found by Mr. King in the Bolopully valley, and by myself in the closely adjacent Mangtoor valley, and at Giddaloor and Putcharla in the neighbourhood of Cumbrun. All these were found at elevations of from 700 to 1000 feet above the sea-level.

From the facts now described I venture to make the following deductions :—

1st. That chipped-stone implements are found in, or associated with, two sets of formations occurring at different levels above the sea.

2nd. That the low-level gravels and conglomerates of the coast-laterite, and the coarse boulder-gravels of the middle grounds, including the great accumulations of quartzite shingle, were deposited or re-arranged into their present form, during one and the same period, and are marine deposits.

3rd. That during the latter part of this period an elevatory movement was in progress, by which the land was raised between 500 and 600 feet. This was followed by a period of quiescence, during which the laterite deposits underwent very extensive denudation, particularly from the action of the rivers, which cut passages for themselves across the belt of recently raised land, and in great measure scoured out the lateritic deposits from the old river-valleys, which had been scooped out of the gneissic rocks probably in much more ancient times.

To this period of quiescence succeeded a period of depression; but to what depth it proceeded we have as yet not sufficient evidence to show; probably it was not very great. During this time the recent coast-alluvium was formed, and a small elevation then brought up the land again to its present position.

4th. It appears to me that there is no evidence as yet to prove or disprove the contemporaneity of the high- and low-level implement-bearing deposits.

5th. It is very improbable that elevatory movements of such great magnitude as those described in connexion with the laterite formations of the eastern coast of India did not affect the whole peninsula, at least to some extent; and there seems to be a good deal of evidence in favour of the idea that, in part at least, the laterite of the

* See Proceedings of the Asiatic Society of Bengal, Sept. 1867.

western coast of India is of the same age as the implement-bearing beds near Madras.   The resemblance in geographical position is complete ; and there is a strong likeness in the mineral characters of the typical developments of the laterite on both coasts, as seen at Tanjore and Cuddalore on the east coast, and on the west coast in the railway-cuttings near Shoranur, in South Malabar, and at Kotium, in Travancore. I have annexed a small map (fig. 1), in which I have endeavoured to give an approximation to a contour-line representing roughly the coast-line which would appear if the land were again depressed to a depth of 500 feet*.   It will be seen from this that the area of the peninsula would be much reduced, and also that a number of islands would appear along the coasts.

As very few data are available for the construction of such a contour-line, allowances must be made for the inevitable rudeness of the attempt.   My object in constructing this map was to indicate the region over which it is desirable that search should be made for further evidences of the extension of the laterite sea.

Discussion.

The President referred to the evidence of Physical Geography to prove that the Deccan was once an island, and to Ethnological data to prove that the people who made the quartzite implements were probably not the original Aryans, but were the ancestors of the Hill tribes, whose nearest affinities are with the aboriginal Australians of the present day.   He was of opinion that the two populations were once nearly or quite continuous, having been subsequently cut into segments by geological changes—and that the makers of the quartzite implements came from the same stock as both these recent tribes, which present the most rudimentary civilization known.

Prof. Rupert Jones called attention to the similarity in the type of these quartzite implements and that of the flint implements of Europe.

Sir Roderick Murchison doubted whether the laterite was a marine formation, as neither in it nor in the lacustrine deposits alluded to had any organic remains been found.

M. Lenormand stated that Obsidian knives, like Mexican types, were found by him, with domestic implements cut out of volcanic stone, under 70 feet of tuff of the primitive volcano of Santorin ; and he considered that before the formation of the first volcano ceramic pottery was brought to Santorin from foreign shores, and, of course, by sea.

Dr. Meryon remarked that the occurrence of the same type of implement in Europe and Asia proved a dispersion of the human race in very ancient times, and that man originated from one centre ; while in later times a divergence of type in the worked objects was a result of the dispersion.

Mr. Prestwich was inclined to believe that greater physical changes had occurred in India since the Pliocene period than in

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* The area which would be submerged is not shaded.

Europe. The implements were so like those of Europe, that their fabricators seemed to have been taught in the same school.

Mr. Foote, in reply, stated that he regarded the laterite as a marine formation, because it occurred all round the coast. All the implements were quartzite, with perhaps one doubtful exception, which was formed of basalt. Stone circles and kistvaens had been found on the surface of the laterite in some localities.

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2. *On worked* Flint Flakes *from* Carrickfergus *and* Larne. By G. V. Du Noyer, Esq.

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S., &c.]

(The publication of this paper is unavoidably postponed.)

[Abstract.]

These flakes have been found by the author in two very distinct positions, namely :—the older in the marine drift (sand and gravel) skirting the shores of the county Antrim and county Down, the maximum elevation being about 20 feet above the sea; and the more recent in the subsoil-clay at all elevations up to 600 feet, near Belfast, Carrickfergus, Larne Lough, and Island Magee. The former are of the rudest forms, highly oxidized or white on their entire surface, but, though imbedded in marine drift, having the chippings around the sides and angles generally sharp. The latter have a comparatively fresh look, though still possessing the characteristic porcellanous glaze; they are regarded by Mr. Du Noyer as possibly the rough materials out of which the historic races in Ireland manufactured the spear- and arrowheads which are found with their sepulchral and other remains.

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3. *On the* Diminution *of the* Volume *of the* Sea *during past* Geological Epochs. By Andrew Murray, Esq., F.L.S.

[Communicated by the President.]

(Abstract.)

The author regards Mr. Darwin's theory of Coral islands as imperfect, from not recognizing the fact of a gradual diminution of the amount of water on the face of the earth. He objects to Mr. Darwin's explanation of the mode in which the islets appear above the water, namely, the dash of the waves breaking the reef, and their wash piling up the débris until it forms dry land; and he quotes the objections of M. de Rochas to the same theory. The opinion of the latter author was that the islands had been raised by a movement of upheaval; but Mr. Murray considers this still more improbable, as we are dealing with a large number of islands scattered over an immense space, and all at one uniform level, only a little above

the surface of the sea ; while the amount of all known elevations is irregular, and increases towards some axis of elevation.

Mr. Murray believes the true explanation to be that the sea is gradually diminishing in volume ; and he regards the Coral islets as a proof that it is so ; at any rate, he remarks that if we apply this condition of things to an area of coral reefs, all as near the surface of the sea as the polyps can make them, we should have a result exactly in accordance with the state of things now existing in Polynesia.

The author then states that the fossils of the older formations being wholly marine, and the thickness of those formations largely exceeding those of later periods, afford evidence in support of the view that the globe was then enveloped in water. In opposition to Sir Charles Lyell's view, that the proportion of dry land to sea was always the same, and the volume of the land above the sea a constant quantity, he maintains that the latter is constantly increasing, and that both the mean and the extreme depth of the sea are constantly diminishing ; and he believes the cause of this constant diminution to be the extreme affinity which water has for the constituent elements of minerals.

Mr. Murray is careful to state his admission that whether there be more or less free water now than at the beginning, there can be neither more nor less of the elementary constituents out of which it is composed. He then refers to volcanic action as showing that the process of the cooling of the earth's crust, and the attendant abstraction of water from the surface are still going on ; and he remarks that although not a particle of water can be present in the molten mineral core of the earth, yet every particle of that core will, when cool, be largely composed of water—and that therefore the amount of water on the surface of the earth must continue to diminish until the earth is cool or the water wholly absorbed. In conclusion, he quotes the case of the Moon as one in which this process of absorption of not only its water, but of its atmosphere also, has been brought to a conclusion.

4. *Has the* ASIATIC ELEPHANT *been found in a* FOSSIL STATE ? By A. LEITH ADAMS, M.B., F.G.S. *With some* ADDITIONAL REMARKS ; by G. BUSK, Esq., F.R.S., F.G.S.

IN December 1867 my attention was directed by a friend residing in St. John, New Brunswick, to a tooth in his possession, and which had been presented to him by the discoverer with the following note :—"A fossil tooth found by Dr. Duggan, in company with Mr. Hodgson, one of H.M. Consuls in Japan, in 1859. At a distance of over forty miles from the sea-shore between Kanagawa and Jeddo, and at the base of a surface coal-bed (80 feet, or thereabouts, from

the general level) the accompanying tooth was found.   To what
animal does it belong ?

<div style="text-align:right">

(Signed)   " R. N. DUGGAN, M.D., Ph.D.,
" *Member Royal Asiatic Society.*"

</div>

The accompanying plaster-of-Paris cast* will suffice to indicate the
dimensions and general characters of the tooth in question.   As to its

Fossil Tooth of Elephas Indicus *from Japan* (three-fourths the
natural size).

condition, it is in a splendid state of petrifaction, with several superfi-

* Deposited in the Society's Museum.

cial cracks (sun-cracks?) on its crown and sides. The weathered state of the tooth and its weight and hardness clearly prove its fossil condition, although the black alveolar-margin stain still borders the sides of the crown, as represented by the brown paint on the cast. The weight equals $3\frac{3}{4}$ lbs.

This penultimate true molar, right side, upper jaw, although partaking of the characters of *E. Armeniacus*, Falc., differs from the latter in its thick plaits, their less approximation, the festooning being carried round the loops of the disks of wear, and the total absence of any mesial expansion.

There is a notice of a fossil elephant's tooth mentioned in the late work on Japan by Sir Rutherford Alcock. I can find no record of the animal having existed in recent times in Japan; and considering the importance of the subject as connected with the Elephant of Asia, I herewith forward an exact cast of the molar, now in the possession of Dr. Fiske, of St. John, New Brunswick, in the hope that future inquiries may be made regarding such an interesting discovery as that of the Asiatic Elephant in a fossil state.

ADDITIONAL REMARKS.   By G. BUSK, Esq., F.R.S., F.G.S.

THE foregoing brief notice and the accompanying cast having been recently sent to me by Dr. Leith Adams, I have hastened to lay them before the Society, fully agreeing with Dr. Adams as to the interest attaching to the discovery he records, and especially if, as seems highly probable, he is right in referring the fossil to *E. Indicus*.

With reference to the latter point, I beg to offer one or two remarks. In the British Museum there is a large part of a fossil molar tooth from China, which, on comparison with the teeth presented by Colonel Gills from Armenia, so exactly resembles them in every respect, that no doubt can be entertained as to its belonging to the same species, namely, *E. Armeniacus* of Dr. Falconer; and as such, I believe, it was regarded by that eminent palæontologist. The occurrence, therefore, of the same form in Japan would not have been very surprising; but, so far as I am able to judge, it is impossible to identify Dr. Duggan's specimen with *E. Armeniacus*. In the first place, as pointed out by Dr. Leith Adams, the crimping of the enamel extends quite round the ends of the disks, and is not limited to the middle portions of them only, as it is in the typical *E. Armeniacus*; and, secondly, the Japanese tooth is at least an inch narrower than those from China and Armenia, or than those described by Dr. Falconer as belonging, in all probability, to the same species, and observed by him in Italy.

The only other species with which any comparison need be made is Dr. Falconer's *E. Columbi*, with some specimens of which, as described by him, the dimensions of the Japanese tooth appear to accord, although the majority of teeth of *E. Columbi* seem to be much wider. The tooth is much curved, a character upon which Dr. Falconer lays much stress in his account of *E. Columbi*. But it differs from that species in the apparently less thickness of the

plates, and especially in the smaller size, and proportionately greater number, of the apical digitations in the hindermost plate.

The dimensions as taken from the cast are as under :—

	inch.
Length when entire, probably	7·4
Greatest width (8th plate)	3·0
Height (8th plate)	4·3
Average thickness of plates on side of tooth	0·56

Ten plates are exposed by wear on the surface of the crown; and one, or it may be two more have been worn away in front, whilst a small plate or talon has been broken off at the hinder end. The disks of wear of the seven anterior plates are entire, the eighth nearly so, whilst the ninth shows three oblong divisions, and the tenth, as above said, exhibits traces of eleven or twelve, or more, apical digitations just beginning to wear. The cast unfortunately affords no clear indication of the sculpturing of the enamel-surface.

The disks are very slightly arched transversely, and have no tendency whatever to a median expansion. The sides are parallel and the ends rounded, and not in the least retroflected. The enamel is strongly crimped, and the crimping extends round the ends of the disks.

From the number of plates and the length of the tooth, I regard it, not as the *penultimate*, but as the *antepenultimate* upper left molar. If met with in the recent condition, no one, I think, would hesitate for a moment to refer it to *E. Indicus*; but when regarded as a fossil, it is interesting and important to notice the points in which it appears to differ from a corresponding tooth of that species. These are :—(1) its considerable curvature; (2) its somewhat greater proportionate breadth, which in M 1 of *E. Indicus*, so far as I am aware, rarely, if ever, exceeds 2·5 or 2·6 inches; and (3) the greater thickness of the plates, which in the Indian species averages about ·48 inch, though it occasionally reaches ·53 inch, and in the lower molars very rarely as much as ·6 inch. But these differences do not appear to be of much importance, and there seems to be every reason to believe that the Japanese fossil tooth belonged to a form of *E. Indicus*, with teeth somewhat larger than the average of the existing one.

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5. *On the* CHARACTERS *of some new* FOSSIL FISH *from the* LIAS *of* LYME REGIS. By Sir PHILIP GREY EGERTON, Bart., M.P., F.R.S., F.G.S.

OF all the noted localities for fossil remains in Great Britain not one exceeds Lyme Regis for the number, variety, and interest of the forms of ancient life which have been there discovered. Ever since the earliest results of Miss Mary Anning's extraordinary success in collecting remains of extinct animals were made known, scarcely a

year has passed without some revelation of Liassic times having been elicited by the assiduity of the collectors in that far-famed locality.   Of fish alone we now reckon thirty-one distinct genera, comprising seventy-nine species; and of the latter not more than two or three have been clearly identified as occurring elsewhere.   The following is a short description of some of the novelties which have occurred in the last year or two.   As the specimens are large and worthy of full pictorial illustration, the more detailed account will be reserved for one of the forthcoming Decades of the Memoirs of the Geological Survey.

OSTEORACHIS MACROCEPHALUS, gen. et spec. nov., Egerton.

The description of this new genus is taken from three specimens in the collection of the Earl of Enniskillen.   The most remarkable features in them are the massive dimensions, and complete ossification, of the bodies of the vertebræ; and these have suggested the generic appellation.   They all appear to belong to one species, characterized by the large size of the head and the multiplicity of the teeth.   It is quite possible that a small fragment of a jaw in the same collection, named by Professor Agassiz *Eugnathus polyodon*, may have belonged to this species, in which case (if proved) the specific name I have adopted will have to be replaced by "*polyodon*."   The fish when entire must have been two feet or more in length; the head measures 7 inches.   The deepest part of the body was at the shoulder-girdle, from which point the outlines gradually converge, until at the ventral fins the depth is $3\frac{1}{2}$ inches.   The bones of the head are largely developed, especially the epitympanic and hypotympanic or quadrate bone.   The latter has a strong articulating condyle for the attachment of the lower jaw.   All the bones in the oral cavity are densely beset with small sharp teeth, associated, on the maxillary, premaxillary, and mandibular bones, with conical teeth of larger dimensions.   The surface of the head was roughly ornamented with elevated blotches of enamel of varying form and size.   The column contained about forty vertebræ, measuring nearly half an inch each in diameter; they are completely ossified.   The neural processes are proportionately strong, and are united to the centres by broad bases.   The pectoral fins are long and broad; the component rays are single for an inch and three quarters, but are bifurcate and cross-jointed in the distal portion of the fin.   The ventral fins are of moderate dimensions, and contain about eight rays each; they are supported by strong pelvic bones.   The dorsal fin is immediately over the ventrals; the interspinous bones supporting it are long and strong.   There are no fulcral or marginal osselets discernible; but the main rays, to the number of a dozen, are preserved.   The anal fin is placed near the tail; it contains seven or eight rays.   The caudal organ is not preserved in any of the specimens. The scales are large and solid, firmly locked together by a pin-and-socket apparatus.   The surface is beset with tubercles and granules of a lustrous ganoine, coarser and more frequent on the scales covering the anterior and middle part of the trunk than on those nearer the tail.

A few obsolete striæ are visible here and there in some of the speci-
mens, terminating in a slightly notched margin ; but as this charac-
ter is very limited in extent, it can hardly be considered of specific
value, as far as the present evidence extends.   This genus belongs
to the Sauroid family of the Ganoid order of Agassiz.

Isocolum granulatum, gen. et spec. nov., Egerton.

This is another novelty from the Lias of Lyme Regis, also in the
collection of the Earl of Enniskillen.   As the anterior part of the
head is deficient it is impossible, in the absence of the teeth, to say,
with any certainty, to what family it belonged.   It has some resem-
blance to the larger species of *Pholidophorus* found in the Solenhofen
slates, but more to the Sauroid genus *Caturus*.   For elegance of
form this fish can vie with a Salmon of modern time, the contour of
the two being very similar.   The specimen is unique.   It measures
18 inches in length, the snout and tail being both wanting.   The
head is small, occupying about one-fifth of the length.   The shape of
the body is fusiform or, rather, elliptical.   The dorsal fin occupies the
exact centre of the back, and the ventral fins a similar position on
the ventral surface.   The anal fin is central between the ventral
fins and the tail.   The depth of the body at the dorsal fin is $4\frac{1}{2}$
inches ; and the contours of the fish converge gradually and symme-
trically fore and aft, until the diameter at the shoulder-girdle is
3 inches and at the tail 2 inches.   The opercular apparatus is rather
slight.   The component plates are finely granulated on the surface.
The column contains forty-six vertebræ well ossified.   The spinous
appendages are slight in the fore part of the column, but behind the
dorsal fin above and the vent below they assume a full and vigorous
development.   In advance of the dorsal fin there are twenty inter-
spinous bones not bearing dorsal rays ; a similar arrangement occurs
in *Caturus*, *Thrissops*, and some other fossil forms, as well as in
Lepidosteus, the *Clupeidæ*, and other recent fishes.   These are suc-
ceeded by seventeen large interspinous bones, bearing the rays of the
dorsal fin ; the two or three anterior rays are short, and above
these fulcral rays the margin of the fin is finely fringed ; the
fifth ray is the largest, but the entire fin is small compared with
the size of the fish ; the rays are cross-jointed at the extremities,
but not bifurcate.   The pectoral fins contain twelve rays each, the
first being very stout and triangular in section ; they correspond with
the rays of the dorsal fin in being cross-jointed in their distal parts
and not split.   The ventrals have a tolerably strong pelvic support
nearly an inch in length ; the fins are comparatively large, measuring
$1\frac{3}{4}$ inch in length, and being composed of twelve rays each ; unlike
the other fins, their rays are bifurcate at their extremities.   The anal
fin occupies a central position between the ventral fins and the tail ;
it contains ten short rays articulated to ten strong interspinous
bones.   The caudal appendage is wanting, but, guided by the large
size and spatulate form of the last vertebral processes, it is presuma-
ble that it was an organ of great power.   The scales are of moderate
dimensions, not so thick as those of *Eugnathus*, *Osteorachis*, and other

Sauroid genera, and not so thin as those of *Caturus, Pachycormus,* and *Thrissops.* They do not vary so much in size as is usual in the afore-mentioned fishes; they also differ from them in the constant repetition of the surface-ornament over the whole body, even to the smaller scales at the root of the tail. This ornament consists of granules of enamel interspersed with fine ridges of the same material, forming together a series of patterns of great beauty. The posterior free margins of the scales are sharply dentate, especially in the posterior parts of the body. The generic title of this fish is grounded upon the remarkable symmetry and balance of parts which it exhibits. If halved or even quartered, the several halves or quarters would very nearly correspond with each other. I know of no other fossil fish of which this could be said.

HOLOPHAGUS GULO, Egerton.

Some years ago I detected, in the collection of Mr. Harrison, of Charmouth, a specimen of a fossil fish evidently belonging to the Cœlacanth family. As this was the first evidence of the occurrence of any member of this family in the Lias (although we were acquainted with several species in the Coal and Permian formations below, and in the Oolites and Chalk above), it interested me much, and I took down a short account of its characters and gave it the generic name of *Holophagus,* with reference to the fact that an entire *Dapedius* is seen in the stomach. This description was not made public until 1861, when Professor Huxley printed it in a note at the 19th page of the 10th Decade of the Memoirs of the Geological Survey of the United Kingdom. The specimen itself passed into the possession of the Jermyn-Street Museum, and still remained unique in 1866, when Professor Huxley reproduced the former description in the 12th Decade, accompanied by a lithographic representation of the fish, and some valuable observations on the affinities of the genus. Last autumn, however, a rude sketch was sent me of a fish recently discovered at Lyme Regis, which I at once recognized to be a magnificent example of the genus *Holophagus.* I have since had an opportunity of examining the original, of which Lord Enniskillen is the fortunate possessor. Of the vast number of fossil fishes which have passed through my hands, I look upon this as the finest and the most important in a scientific point of view, as it displays in most perfect condition all the remarkable features of this most curious and anomalous family. The individual is rather more than one-third longer than the specimen first described, but I am unable to detect any points of specific difference. As regards the anatomical details alluded to in the former description, this specimen yields nothing to alter and little to add; the most characteristic features of the genus are intelligible in both. The occurrence of a double styliform bone supporting the anal fin, analogous to that at the base of the second dorsal fin, is the only additional feature I have to notice. The principal value of the recently discovered specimen is the preservation of the head. As Professor Huxley has made this subject his own by the admirable manner in which he

has worked out the details of the cranial osteology in the other genera of the Cœlacanths, and as he has undertaken to follow up that inquiry by a minute description of the specimen now under consideration, in a future Decade, I shall only remark that the contour of the head is remarkably similar to that of *Macropoma* in the declivity of the frontal line and the general form of the component bones, and that this specimen, taken as a whole, substantiates entirely the truth of Professor Huxley's demonstration of the remarkable persistence of type prevailing in this particular family through the vast periods of geological time which must have elapsed between the deposition of the lower beds of the Coal-measures and that of the Chalk formation; and that I entirely agree with him in the restricted view he takes of the Cœlacanth family, by excluding many of the genera assigned to it by Professor Agassiz.

EULEPIDOTUS SAUROIDES, spec. nov., Egerton.

When Professor Agassiz first propounded his new classification of fishes, the fossil forms then known were quite insignificant in number compared with the voluminous lists we now possess. It is therefore not surprising that the progress of discovery, by disclosing new forms, should have rendered it imperative upon subsequent observers to suggest some modifications of the original scheme, especially with reference to the Ganoid order, with a view to arrange systematically these new materials. The subject of the present description raises the question of the validity of the distinctions between the Lepidoid and the Sauroid families of the Ganoid order, as proposed by Agassiz. The genera *Lepidotus* and *Eugnathus* may be selected as fair types of the two families. The former is a massive fish, with a thick head and blunt muzzle, in form very much resembling a Carp of the present day; the teeth vary from the crushing type (resembling those of the Pycnodonts) to a more elongated conical form. The body is covered with thick rhomboidal scales of large and tolerably uniform size on the flanks and belly; the fins are of moderate dimensions, not calculated for swift progression, and the tail is homocercal. The latter, on the contrary, is a slender fish, tapering gradually from head to tail; the teeth are of two sizes, as in *Lepidosteus* of the present day, the long and sharp prehensile teeth being intermixed with small needle-shaped teeth, for retaining the slippery prey; the dorsal fin is not far back, and the semiheterocercal tail is an organ of great power; the scales are small compared with the size of the fish, and vary much in shape and size in the different parts of the body; in particular on the ventral region, and especially around the insertions of the fins, the scales become as much elongated as the scales of *Ptycholepis*. In every respect, therefore, this is a fish of prey, having all its organization specially adapted for a predatory life, as the former may be considered adapted for sluggish habits and a testaceous or, may be, herbaceous diet. The subject of this notice occupies an intermediate station between these two forms. The body is more elongated than in any *Lepidotus*—as much so, in fact, as in *Eugnathus Philpotiæ*. The head, although

not acuminate, is nevertheless more nearly so than in other *Lepidoti*, and resembles in form and proportions that of *Pachycormus*, another Sauroid genus.   The teeth are of two sizes, and constructed on the same plan as the teeth of the undoubted Sauroids. The fins resemble those of the *Lepidoti* in size, structure, and position ; but the tail is more like that of a *Eugnathus*.   The scales partake of both characters—those on the shoulders resembling *Lepidotus*, those on the belly being lineolate, as in *Eugnathus*.   The ornamentation of the surface is generally regarded as only of specific value ; but on the whole it is more like that of *Eugnathus* than that of *Lepidotus*.   I am acquainted with several specimens of this form, some perfect, some only fragmentary ; the latter were found arranged partly with *Eugnathus*, partly with *Lepidotus*, until the discovery of a perfect specimen led to the recognition of their true nature.   Lord Enniskillen's best specimen measures 2 feet 2 inches in length, without the tail, while my most perfect specimen measures 2 feet within the same limits.   The following table gives the comparative measurements of the two specimens :—

	ft.	in.		ft.	in.
Length	2	2		2	0
Head	0	7		0	7
Nape to dorsal fin	0	7		0	8½
Dorsal fin	0	3½		0	3½
Dorsal fin to tail	0	9		0	9
Tail (imperfect)	0	4	... { Upper lobe wanting }	0	5
Dorsal to ventral fin	0	9½		0	8
Ventral to anal fin	0	4½	Wanting		
Anal to tail	0	7	Wanting		
Depth at shoulder	0	7½		0	6
Depth at dorsal fin	0	7			
Depth behind dorsal fin	0	6		0	5
Pedicle of tail	0	3		0	3
Lower jaw	0	3		0	3½
Breadth of head				0	2½

These measurements correspond sufficiently to enable us to consider the two specimens as belonging to the same species ; the details, therefore, will be taken from one or the other, according to the state of preservation of the parts under description.   A third specimen, belonging to Lord Enniskillen, is rather more slender than either of those yielding the above dimensions.

It will be seen from the Table given above that the head is about one-fourth of the entire length, exclusive of the caudal fin.   The greatest depth of the body is at a point about halfway between the occiput and the first ray of the dorsal fin, whence it decreases gradually to the pedicle of the tail.   The dorsal fin is situated over the ventral fins ; it is preceded by five fulcral spines, and has marginal rays fringing the anterior edge of the fin ; it comprises twenty rays, the sixth being the longest, measuring about three inches in length in one specimen, and four in the other.   The pectoral fins are long and broad, containing twenty rays each.   The ventral and anal fins are small.   The component rays of all the fins are bifur-

cate, and frequently cross-jointed. The tail is a powerful organ, more so than in the typical *Lepidoti* : the upper lobe is strengthened by a series of strong scales imbricating the upper edge of the fin ; it contains eighteen long rays : the lower lobe is composed of twenty rays, and has the inferior margin invested with fulcral scales. All the component rays are cross-jointed, and the extremities frequently bifurcated. The head, in shape, resembles that of *Pachycormus*, being broader and more blunt-nosed than in *Eugnathus*, but smaller and more elongated than in *Lepidotus*. The lower jaw is straight, and measures from 3 to $3\frac{1}{2}$ inches ; it is furnished with numerous sharp hooked teeth of irregular size, resembling the dental apparatus of the true Sauroid fishes. The maxilla is $2\frac{3}{4}$ inches in length ; the teeth in this bone are smaller and more irregular than those on the mandibles. All the head-bones are of dense structure, and have a coarse surface-ornament composed of granules and blisters of ganoine irregularly disposed in clusters here and there, the remainder of the surface being smooth and lustrous. The scales on the anterior part of the trunk have all the characters of the scales of the typical *Lepidoti* ; but on the ventral surface of the body they assume an elongated form, characteristic of the scales in this region of the *Eugnathi*. This character is common also to two species now classified as *Lepidoti*, namely, *Lepidotus fimbriatus* and *Lepidotus serrulatus*, the former from Lyme Regis, the latter from Barrow-on-Soar. In his description of the latter species, Agassiz remarks upon this elongation of the scales on the ventral surface ; and Pictet alludes to the former as a species whose generic position is still doubtful. Agassiz only knew it by some very fragmentary specimens ; perfect ones have since been found, and prove that it had sharp teeth and elongated ventral scales, although the body had the thickish outline of the true *Lepidoti*. I am of opinion therefore that these two species may be classified as a subgenus with the subject of this memoir, under the name of *Eulepidotus*, and as forming part of the Sauroid rather than the Lepidoid family. As far as our present knowledge extends, this form is restricted to the Lower Lias.

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6. *Note accompanying some* Fossils *from* Port Santa Cruz, Patagonia. By Capt. Thomas Baker, Lieut. Royal Naval Reserve.

[Communicated by the Assistant-Secretary.]

(Abstract.)

The entrance to the river Santa Cruz, which is about 134 miles north of the Straits of Magellan, lies between a high steep cliff on the south and a low shingle point on the north. The estuary of the river runs in a north-westerly direction for a few miles, and then divides into two branches :—a northern, which is a sluggish shallow stream abounding in shoals ; and a western, which is of more importance to navigation, and is the true river Santa Cruz. From the estuary the western arm takes a south-westerly course, and then bends sharply to the west, flowing between cliffs from 200 to 300 feet in height, which at present are not washed by the river, being bordered

by a sloping beach about 300 feet in width.   The lowest stratum in the cliff is a blue rock, upon which is a bed, 4 feet thick, largely composed of a gigantic species of oyster (*Ostrea Patagonica*, D'Orb.*); upon this rests a shelly conglomerate, composed almost entirely of shells, and rendered hard and coherent by a calcareous cement.   The upper portion of the cliff, from the top of this conglomerate to the summit, consists of a blue sandy clay containing pebbles and small shells.   The actual height of the cliff at this point is 280 feet.

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7. *On* Jurassic Deposits *in the* North-west Himalaya. By Ferdinand Stoliczka, Ph.D., F.G.S., Palæontologist to the Geological Survey of India.

In Mr. Tate's paper on the South-African fossils † several statements occur which, if admitted as correct, would render very discouraging the prospects of an accurate study and the determination of the age of Jurassic rocks in extra-European countries.   I do not at present wish to pronounce an opinion upon Mr. Tate's discussions and ideas on the " distribution of the lower members of the Mesozoic rocks over the surface of the earth, and the laws that apparently were in operation during their deposition ;" but I may be allowed to say a few words with reference to Himalayan Jurassic rocks, with which I am personally acquainted.

The rocks to which I allude are those of the Spiti valley and the neighbouring districts of the north-west Himalaya.   Mr. Tate remarks (*loc. cit.* p. 168), " for though Dr. Stoliczka has endeavoured to establish a definite succession of strata analogous to several members of European Juras, yet, in my opinion, he has failed to establish a true correlation ; for the fossils which in Europe belong to determinate stages in the geological scale are confusedly associated together in the various members of the Spiti equivalents of the Jurassic rocks."

It is evident that every geologist who is not able to procure access to my original papers ‡ will believe that my survey of the Spiti valley and the determination of the fossils were only a guesswork, and that what European geologists call Lias, Dogger, and Malm are in the Himalaya only represented by *one equivalent of Jurassic rocks, in which fossils of the different formations are confusedly associated*.

Though I cannot doubt for a moment that anybody in possession of my papers would be able to form for himself an opinion as to the correctness or incorrectness of Mr. Tate's statement, still a short account of the Jurassic deposits as developed in the Spiti valley may be welcome

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* [With the exception of this species, the fossils collected by Capt. Baker differ from those South-American Tertiary forms described either by D'Orbigny or by Sowerby (in Darwin's ' South America '), although some of them, *e. g.* a *Struthiolaria*, a *Turritella*, and a *Natica*, appear to be closely allied to those collected by Darwin.—Ed.]

† Quart. Journ. Geol. Soc. vol. xxiii. p. 139.

‡ " Sections across the North-west Himalayas from the Sutlej to the Indus, &c.," and " Summary of Geological Observations, &c.," Mem. Geol. Survey of India, 1865–66, vol. v. pt. 1. p. 1, and pt. 3. p. 337.

to many readers of this Journal. However, before entering into any details, I must particularly direct attention to the meaning of the words "*Jura*" or "*Jurassic*," as applied by Mr. Tate. On p. 168 (*loc. cit.*) the following passage is to be found. "The Jurassic series . . . . . is reduced . . . . . to beds representing the Lower and Middle Jurassic beds, from the Lias to the Oxford Clay inclusive," &c. This plainly shows that Mr. Tate uses term the *Jurassic* as including the three formations known under the names of Lower, Middle, and Upper Jurassic rocks, or Lias, Dogger, and Malm, or Black, Brown, and White Jura, &c.

In my memoirs, previously noticed, I have, among the Jurassic rocks of the Spiti valley and the North-west Himalaya, distinguished the following formations :—

1. Lias . . . . $\begin{cases} a. & \text{Lower Tagling limestone.} \\ b. & \text{Upper Tagling limestone.} \end{cases}$

2. Dogger . . . . $\begin{cases} c. & \text{Jurassic slates (not specified).} \\ d. & \text{Spiti shales.} \end{cases}$

3. Malm (?) . . . .   *e.* Gieumal sandstone.

1. Lias.

a. The *Lower Tagling limestone* generally rests unconformably on the Lower or Upper Triassic* limestone ; it is of a dark grey colour and often has an oolitic structure. The weathered surface of the rock is usually rusty brown, showing that it contains a considerable admixture of sandy ingredients.

The characteristic fossils † of this limestone are *Terebratula gregaria*, Sss., *T. pyriformis*, Sss., *T. punctata*, Sow., *Waldheimia Schafhæutli*, Stopp., *Rhynchonella obtusifrons*, Sss., *R. pedata*, Bronn, sp., *R. fissicostata*, Sss., *R. Austriaca*, Sss., *R. variabilis*, Schloth., *R. ringens*, Her., *Pecten Valoniensis*, Defr., *Lima densicostata*, Quenst., *Avicula inæquivalvis*, Sow. Besides these, I have described three new species of *Belemnites* (*B. Budhaicus*, *B. bisulcatus*, and *B. Tibeticus*), and a large number of other new species of Mollusca, which it is not necessary to mention here in particular, as they have no special value in point of a comparison of our deposits with those of Europe. All the above-noted species, however, are well-known Liassic fossils ;

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* I have not as yet been able to distinguish properly between the Lower and Middle Triassic beds. The limestones which appear to represent these divisions are perfectly alike. It is, however, possible that (making use of the latest researches of Alpine geologists) the beds with the *Ceratite-like Ammonites* may be shown to represent the Lower, and those with the Hallstadt *Arcestes* and *Orthoceras* the Middle Trias. As Upper Trias I have quoted the beds with *Megalodon triqueter* and *Dicerocardium*. I also stated that if the name *Rhætic* had to be retained, it could possibly be applied to these beds ; but it is hardly necessary to use it for the beds with the Kössen Brachiopoda *Terebratula gregaria*, *Rhynchonella obtusifrons*, &c. ; for the fauna of these beds is a truly Liassic one. I have discussed this point with several of my friends at home, and they mostly agree as to the *Liassic* character of their fauna.

† I must particularly remark that all the fossils which I quote here have been collected either by my colleague, Mr. T. R. Mallet, or myself. None have been accepted on foreign authority.

and most of the Brachiopoda have as yet only been found in the lowest beds of the Lias, known to European geologists under the name of Rhætic or Avicula-contorta beds, or under the name of Kössner-Schichten. None of the species have to my knowledge been found in other than Liassic beds, and I have not met in the Himalayas with an exception from this rule.

b. The *Upper Tagling limestone* is of a similarly dark-grey colour as the previous one, but it is generally dolomitic. Stratigraphically both are rather difficult to separate. Fossils have been met with only in one place; but those which have been identified are the same which occur in the Liassic beds on the Hierlatz (Lower Austrian Alps), and of which I published a monograph in 1861 (Sitz. Akad. Wien, vol. xliii. p. 157). The species are *Chemnitzia undulata*, Rss., *Trochus latilabrus*, Stol., *T. epulus*, d'Orb., *T. attenuatus*, Stol., and *Terebratula Sinemuriensis*, Opp. Other species could not have been identified with sufficient accuracy; but except a Belemnite, which resembles *B. bisulcatus* of the lower beds, none of the fossils have been found common to any of the other Jurassic strata of the Spiti valley.

2. Dogger.

c. I met, above the *Lower Tagling limestone*, near Gieumal, a thin bed of a clayey slate, which gradually appears to pass into the Spiti shales overlying the same. The only fossils were fragments of *Belemnites*, and a *Posidonomya* which seems to be identical with *P. ornata*, Quenst., of the Lower Oolite.

d. *The Spiti shales* occupy a very distinct horizon, and are lithologically, as well as by their exterior appearance of black colouring, very easily separated from any of the other strata. Nearly all the Jurassic Cephalopoda which have at different times been brought or sent home by Himalayan travellers have been obtained from these beds.

The following are their characteristic species :—*Rhynchonella varians*, Schloth. sp., *Pecten lens*, Sow., *Trigonia costata*, Park., *Ammonites macrocephalus*, Schloth., *A. Parkinsoni*, Sow., *A. curvicosta*, Opp., *A. Brackenridgii*, Sow., *A. liparus*, Opp., *A. triplicatus*, Sow., *A. biplex*, Sow., and *Belemnites* canaliculatus*, Schloth. A large number of other new species of Mollusca have been found and described, and several of these are identical with species from the Middle Jurassic deposits of Cutch.

3. Malm (?).

e. *Gieumal Sandstone.*—The beds which I have distinguished by this name generally rest conformably on the Spiti shales, from which, however, they are lithologically very distinct. They are usually

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* The Liassic *B. clavatus* is doubtful; and similar Dogger specimens which have been referred to it in Europe are now generally regarded as belonging to different species, though the distinctions have as yet not been satisfactorily proved.

thin-bedded, partially siliceous and conglomeratic, partially calcareous sandstones of a light-brown or yellowish colour.

The only two European species which I have met with in these beds were *Avicula echinata*, Sow., and *Amusium* (*Pecten*) *demissum*, Bean. Our specimens of the former perfectly agree with those of the Cornbrash type, and of the latter with Römer's *Pecten vitreus* from the Upper Oolite of Germany. With reference to the development of the Jurassic deposits in the Spiti valley I have classed these beds as " Upper Jurassic," stating that they probably may be the representatives of the European " Malm." I based my opinion upon stratigraphical reasons as well as upon the discovery of a number of fossils such as an *Ostrea*, a *Gryphea*, *Mytilus mytiloidea*, Blf., *Pecten bifrons*, Salter, *Anatina Spitiensis*, Stol., *Opis*, and others, all of which are more or less related to Upper-Jurassic types of shells.

The Gieumal sandstone is overlain by Cretaceous rocks.

This short account of the Jurassic deposits, as represented in the Spiti valley, and characterized by a number of well-known European species, will, I trust, show how far Mr. Tate's statements with regard to the failure of establishing a correlation between similar deposits in Europe and the Himalayas is correct. I cannot, indeed, perceive upon what grounds those erroneous statements were made, but I am sure they could not have been pronounced upon anything like a careful examination of my memoirs on the Jurassic and other rocks of the North-west Himalaya. I have not quoted a single satisfactory instance where the same species has been found to be common to two of the five divisions into which I have separated the Jurassic deposits of the Spiti valley. Where is there anything like what Mr. Tate calls a confused association of fossils *belonging to determined stages of the European Juras* to be found in the Jurassic beds of the Himalayas?

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8. *On a true* COAL-PLANT (Lepidodendron) *from* SINAI.
By J. W. SALTER, Esq., A.L.S., F.G.S.

(Abstract.)

SOME years ago Sir R. I. Murchison received from an officer travelling in Arabia some sandstone specimens, picked up in the desert of Sinai. One of these was a portion of a *Lepidodendron* (indicating the existence there of the true Coal-formation), preserved in thin-bedded sandstone, harder than Coal-sandstones usually are.

It cannot be identified with any known European species. The scars are peculiar in form, the leaf-attachment being placed very far forward, and the ridge arched.

Mr. Salter describes it as follows :—

LEPIDODENDRON MOSAICUM, spec. nov.

Scars rather square, not more than a quarter of an inch in length, and about the same in width, arched in front, bluntly acuminate behind. The leaf-attachment placed on the anterior portion, very

much arched, lunulate, and narrow, with distinct but not very prominent edges.

9. *On some* FOSSILS *from the* MENEVIAN GROUP. By J. W. SALTER, Esq., A.L.S., F.G.S., and H. HICKS, Esq.

[The publication of this paper is postponed.]

(Abstract.)

THE authors, after describing the localities and stratigraphical relations of the Menevian group, proceed to describe the following species :—

Paradoxides aurora, Salter, represented by a few imperfect heads, unattached pleuræ, &c. Localities, Porth-y-rhaw and St. David's.

P. Hicksii, Salter. This species presents a singularly intermediate character, reminding us equally of *Paradoxides* and *Anapolenus.*

Conocoryphe bufo, Hicks, represented by a few separate heads, and one with six body-rings attached. Localities, Porth-y-rhaw and St. David's.

C. applanata, Salter. Young specimens show all the metamorphoses observed by Barrande. The characters of such genera as *Agnostus* and *Microdiscus* are as clearly seen in the embryo of *Conocoryphe* as in the adult state of those genera. Localities, Porth-y-rhaw, St. David's, Maentwrog, and Dolgelly.

C. (?) *numerosa,* Salter. Of this species, a part of the head and six thoracic rings have been found. These, however, show characters sufficient to indicate that it is specifically, if not generically, distinct from the others. Localities, Porth-y-rhaw and St. David's.

10. *Report of recent* EARTHQUAKES *in* NORTHERN FORMOSA. By H. F. HOLT, Esq., H.M. Consul at Tamsuy.

[Communicated by the Secretary of State for Foreign Affairs.]

(Abstract.)

THE first shock felt in the northern end of the island took place on the morning of the 18th of December, 1867, and lasted about fifteen seconds. Many buildings were destroyed, and many lives lost, in Tamsuy. About fourteen minor shocks were felt during the same day, and on the 20th another violent shock occurred.

At Kelung the whole harbour was left dry for a few moments ; and the water returning in one vast wave, rushed into the town itself. Large landslips have taken place, and several villages between Kelung and Tamsuy have been destroyed.

11. *Memorandum on the* COAL-MINES *of* IWANAI, ISLAND OF JESSO, JAPAN. By A. B. MITFORD, Esq.

[Communicated by the Secretary of State for Foreign Affairs.]

(Abstract.)

THE coal-mines lie two miles inland from a village called Kaianoma, about seven miles across Strogonoff Bay. Four seams of coal have been discovered; two of them are from 4 to 6 feet thick, one is about 3 feet thick, and the fourth, which has not yet been thoroughly examined, is about 1 foot thick. The coal is soft, yields from 10 to 12 per cent. of ash, and from 30 to 35 per cent. of gas. On first being lighted it sends out a thick black smoke, but soon burns with a clear strong flame, and leaves no clinker.

An experiment was made with some of the coal picked out from the surface of the seams, in the galley-fire of H.M.S. 'Salamis,' under the superintendence of the chief engineer. 79 lb. of coal yielded 17·27 per cent. of ash, 1·5 per cent. of clinker, an average volume of smoke, and a strong and durable flame.

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12. *On a* NEW SPECIES *of* FOSSIL DEER *from* CLACTON. By W. BOYD DAWKINS, Esq. M.A., F.R.S., F.G.S.

[PLATE XVII. & PLATE XVIII. figs. 1–8.]

CONTENTS.

1. *Introduction.*—In the collection of fossil mammals found in the freshwater deposits of Clacton by Mr. John Brown, of Stanway, and now in the British Museum, is a series of antlers, forty-one in number, which Mr. Davies could refer to none of the fossil species of the genus *Cervus*. A careful examination has convinced me of the truth of his conclusion, and that they indicate a species of deer hitherto unknown, not only in Britain but also on the Continent. For it I propose the name *Cervus Browni* in memory of Mr. John Brown, to whose indefatigable labour in collecting fossils we owe very much of our knowledge of the Pleistocene Mammalia. Dr. Falconer, whose attention was directed by Mr. Davies to some of these antlers, considered them to belong to a species distinct from the *Axis* of the Crag and Forest-bed [*], being unaware at the time that the nearly perfect

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[*] 'Palæontological Memoirs,' vol. ii p. 478. In Brown's Clacton collection in the British Museum is a very extensive series of Deer-horns nearly all belonging to one species. They are all terete, with a single brow-antler given off very low, as in the Val d'Arno *Axis*, but a little lower and pointing more forwards above the brow-antler. There is generally a long reach of beam with no branch. How the beam terminates is not shown. In size it is like Mr. King's *Axis* from the Crag and Forest-bed, but it differs in the brow-antler being given off lower, and in not having the same pronounced double curve. The species is evidently distinct (*Cervus Clactonianus*).

antler, Plate XVII. fig. 4 (which shows that the Clacton deer had no affinities with any round-antlered deer), belonged to the series of fragments which he inscribed in his note-book as those of *Cervus Clactonianus*, and considering that the antler in question, which is taken as the type of the species, belonged really to *Cervus dama* *. I have therefore felt justified in designating the species after its discoverer, whose name has been as yet ignored in terminology, instead of adopting Dr. Falconer's manuscript name, which he never attempted to define.

Evidence derived from antlers is, in the main, to be looked upon with suspicion, because of the great variation in form that they present at different ages. In this case, however, the large number shows that the type was persistent in a group consisting of forty-one animals, no two of the antlers having belonged to the same individual. Those of the right side are twenty-four in number; and out of the whole, fourteen have been forcibly torn from the skull, twenty-five have been shed, and two are mere fragments of tynes. Out of them I have chosen a series (Pl. XVII. figs. 1–7, Pl. XVIII. figs. 1, 2) to illustrate the characters of the species.

2. *Description.*—The antlers (Pl. XVII. figs. 1–7, Pl. XVIII. figs. 1, 2) are nearly smooth, being traversed merely by broad and shallow depressions for the reception of the nutrient blood-vessels of the velvet. They are set on the skull obliquely to the axis of the beam, as in the Red-deer, Fallow-deer, and Irish Elk. The pedicle (Rosenstöcke) (Pl. XVIII. figs. 1, 2) is round and short, varying in length from 0·8 to 1·1 inch. The burr, or rose of the Germans, is uncertainly developed, being large and sharply defined in some (Pl. XVII. fig. 4, Pl. XVIII. figs. 1, 2), and but rudimentary in others. It presents a rounded outline. Immediately above it, the brow-tyne, *b*, is given off, nearly at right angles to the axis of the beam; the angle, however, varies slightly in different individuals (Pl. XVII. figs. 1, 4, 5; Pl. XVIII. fig. 1). It is cylindrical in section, with a direction somewhat downward basally, and upward as it tapers to its extreme end. It is sometimes straight. After giving off the brow-antler the rounded beam bends downwards, as far as the palmation (*k*), which marks the base of the second or bez-antler (Pl. XVII. fig. 4, Pl. XVIII. fig. 1, *c*), and is also slightly curved forwards. Two antlers present a remarkable variation from the ordinary type: in the one a rudimentary antler springs out of the base of the brow-tyne, *b*; in the other (Pl. XVII. fig. 5), an accessory brow-tyne, *b'*, is thrown off from the beam at a distance of 1·75 inch above the normal brow-tyne (*b*). This variation is also found in an antler of a Fallow-deer in the College of Surgeons. In an antler of *Cervus elaphus*, also in the same collection, there are three brow-tynes. The second tyne (Pl. XVII. fig. 4, Pl. XVIII. fig. 1, *c*) is shaped somewhat like the first; but it springs from a palmated base, and is slightly compressed horizontally, so that the section presented is oval. The variations in direction noticed in the

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* *Op. cit.* vol. ii. p. 480. Specimen No. 27876, quoted as "*British Museum Specimen of C. dama.*"

brow-tyne are repeated also in the second, or bez-antler; both are
nearly of the same length.   From the base of the second tyne, c, the
beam gradually becomes more and more flattened up to the palmated
third (Pl. XVII. fig. 4, d), which is unfortunately broken in all the
specimens; thence it gradually expands into the broad and flattened
crown (fig. 4, h), the summit of which has been broken away from
the nearly perfect antler, fig. 4, chosen as the type of the species.
It presents, however, two broad, oval, fractured surfaces, which
meet at the point h, where the texture becomes dense and hard, in-
dicating that the hard cortical layer of the antler was not far dis-
tant; while, on the other hand, the loose texture in the centre of each
of these surfaces shows that the crown was prolonged some little
distance in their directions.   An inference might therefore be drawn
that not very much of the apex is lost, merely two, or at most three
tynes.   Fortunately, however, we are not left to guess at the shape
of the latter.   A broad palmated fragment, possessed of two tynes
(Pl. XVII. fig. 7, e and f), was found in association with the antlers,
which cannot be referred to the Red Deer or Irish Elk, found also at
Clacton.   The deep excavation between the tynes would forbid its
being identified with a palmated fragment of antler of Reindeer,
a species as yet unknown in Essex, Suffolk, or Norfolk; and there-
fore the supposition that it belongs to *Cervus Browni* amounts
almost to a certainty; and if so, then it could only belong to the
crown.   The broad and deep excavation, fig. 7 h, above mentioned,
brings the cortical layer of dense osseous tissue on either side into
juxtaposition, and explains exactly why the two layers should be
thus brought together at the point h of the fractured apex of fig. 4.
I have therefore restored the crown of the antler, fig. 4, according
to the light thrown upon it by the fragment fig. 7.   At the base of
f, in fig 4, a small rounded back tyne is given off in a backward and
upward direction.   The beam, looked at from behind, presents a
somewhat sigmoidal contour, the basal eighth being abruptly re-
flected.

3. *Measurements.*—In the following Table the variations in the
the size of the antlers are shown.   They are not compared with those
of Fallow-deer, because in the latter the antlers have been modified
to such a degree by domestication that their measurements are of
very little value.   It is sufficient to say, in general terms, that the
antlers of the Clacton deer correspond in size with the average of
those of the Fallow-deer in the English collections.

The maximum circumference of the beam is 5·8, the minimum
30 inches.

Table showing the variations in the size of the antlers of
Cervus Browni.

	Brit. Mus. 27876.	27883.	37778.	27976.	37778.	37778.	37778.	37778.	37778.	37778.	37778.
Circumference above the burr (a)	5·4	5·4	5·5	...	...	5·0	4·0	6·8	3·8	6·2	5·2
Maximum length of brow-tyne (b).........	5·4	4·8	6·5								
Length of beam between brow- and bez-antler	6·5	7·0	7·8	...	...	...	5·8	...	...	6·7	
Breadth of bez-antler (c)	1·5	1·05	1·35								
Length of bez-antler	5·4	5·0									
Length of beam between bez-antler and third tyne	3·6										
Breadth of third tyne (d)	1·75										
Breadth of back tyne (g)	0·75										
Length of beam from base to back tyne ...	18·0										
Inner length of pedicle (Rosenstöcke) (2)	...	0·62	1·1	0·8	0·8	...	...	...	...	0·7	0·92
Circumference of pedicle	...	4·8	5·0	5·0	5·3	...	...	...	...	5·6	4·1

4. *Comparison with* Cervus dama.—The antlers of *Cervus Browni* are totally unlike those of any existing species excepting *Cervus dama*, to which they approach so closely that the type specimen, fig. 4, was considered by Dr. Falconer * to belong to the latter. The basal half, indeed, so strongly resembles the corresponding portion of that of *Cervus dama* that it would be almost impossible to differentiate fragments from which the coronal portion had been broken away. But the resemblance ends at the second tyne (c). If the series of antlers of *Cervus Browni* (figs. 1 and 7) be compared with those of the Fallow-deer which have been reproduced from Professor Blasius's † valuable work, there is this important difference visible : in the former (Pl. XVII. fig. 4), the third tyne, *d*, is present on the anterior aspect, while in the latter (Pl. XVIII. figs. 3–8) it is altogether absent. With this exception, the antlers of the two species are most closely allied; and Pl. XVII. fig. 4 corresponds almost exactly with Pl. XVIII. fig. 5, the third of the series of antlers selected by Professor Blasius as typical of *Cervus dama*. To the objection that the development of the third anterior tyne may have been an accident, it may be answered that it is to be found in none of the endless variations of form assumed by the antlers of

* *Op. cit.* vol. ii. p. 480.
† Fauna der Wirbelthiere, vol. i. fig. 237. Braunschweig, 1857.

the Fallow-deer, and that it is presented also by a far more an-
cient cervine species from the Crag of Norwich.

5. *Probable Age of the Freshwater Strata at Clacton.*—The affi-
nities of *Cervus Browni* with the Fallow-deer are so strong that,
with the exception of the development of the third anterior tyne,
the antlers are identical in size and form.   The latter, however, has
never been proved to occur in the fossil state in Northern or Central
Europe, but probably owes its introduction into France, Germany,
and Britain to the fostering care of man, at a comparatively modern
period.   It has, indeed, been assumed by Dr. Fleming * that the
animal is indigenous to Scotland; but his assumption is based on an
equivocal passage of Lesley, that has no bearing on the point,
while Professor Owen † leaves the question altogether open, very
much as he found it.   In Britain the most ancient traces of its ex-
istence are to be found in the Roman refuse-heaps; and therefore it
is highly probable that its introduction, like that of the buffalo into
Italy, was owing to the Romans.   In Germany the animal has been
quoted by Dr. Rütimeyer ‡ as occurring in the Pfahlbauten; but since
the publication of his fauna he has found reasons for modifying his
opinion.   Its true habitat is the shores of the Mediterranean and
the Taurus district to the north of Syria §.   In Spain, Sardinia,
and Algiers, it rivals the Red-deer in size.   It must therefore be
looked upon as an animal not indigenous in Central or Northern
Europe, but as a dweller, in its natural state, in the hot climate of
the south.   If we assume, legitimately as it seems to me, that
Cervus Browni lived under somewhat similar conditions to those
under which the wild Fallow-deer now lives, the climate of Britain,
during the time that the remains of animals were being swept down
by an ancient river to be deposited at Clacton, must have been much
warmer than it is at the present day,—a condition that would insu-
late the deposits from all those of Postglacial age that were formed
under a lower temperature than that now obtaining in Northern
France or in Britain.   The animals found at Clacton consist of *Felis
spelæa*, Bison or Urus, *Cervus elaphus*, *Cervus megaceros*, *Cervus
Browni*, *Equus*, *Rhinoceros leptorhinus* (Owen)‖, and *Elephas antiquus*,
of which the first six are peculiar to the Pleistocene deposits, while
the last two are found also in the Pliocenes of France and Italy.   One
important group of mammals characteristic of Postglacial strata is

* British Animals (1828), p. 26.
† Brit. Fos. Mam. pp. 483, 484.
‡ Fauna der Pfahlbauten der Schweiz, 4to, Basel, p. 62.   M. Lartêt informs
me, in a letter, that now Prof. Rütimeyer believes that the Fallow-deer has not
yet been proved to occur among the animals found in the Swiss lakes.
§ Blasius, *op. cit.* p. 455.
‖ The identity of the British species described by Prof. Owen (1846) under
the name of *R. leptorhinus*, Cuvier, by the author of this essay under the name
of *R. leptorhinus*, Owen, in 1867, and by Dr. Falconer, in the essay published
in the Palæontological Memoirs, in 1868, as *R. hemitœchus*, with the *R. Merkii*
of Dr. Kaup, determined in 1861, is considered by M. Lartêt beyond all doubt.
("Note sur deux têtes de Carnassiers Fossiles et sur quelques débris de Rhinocéros
provenant des découvertes faites par M. Bourguignat dans les cavernes du Midi
de la France," Annales des Sciences Naturelles, série 5. tome viii. pp. 156 & 193.)

eloquent by its absence—the Reindeer, Musk-sheep, and the other members of the Arctic division, that are more or less abundant in the later river-deposits. Negative evidence is of comparatively small value by itself; but here it adds cumulative weight to the testimony afforded by the unique series of cervine antlers, that the fresh-water beds of Clacton were formed under conditions of climate warmer than those under which we now live, and altogether differing from those under which the Postglacial gravels were deposited. As compared with the mammalia of the Forest-bed, the only species in common are the Red-deer, Irish Elk, and Horse.

The *Rhinoceros Etruscus* of the forest-bed is represented by the *Rhinoceros leptorhinus* (Owen) at Clacton; but this does not help us to the differentiation of the two deposits, because both species are found side by side in the Pliocene strata of the Val d'Armo.

The presence of the cave-Lion, on the other hand, points in the direction of the Postglacial series. In fine, all that can be pre-dicated of the geological horizon of the freshwater bed at Clacton is, that it forms a term in the series of strata to which the Lower Brick-earths of the Thames valley belong (a series apparently show-ing a gradual passage from the Forest-bed towards the later river-deposits termed Postglacial), and that it was formed before the im-migration of Arctic mammals into Britain.

DESCRIPTION OF THE PLATES.

PLATE XVII.

Figs. 1–6. Series of right antler of *Cervus Browni*, one-fourth the natural size, numbered in the British Museum:—(1) 27926, (2) 37778 A, (3) 37778 B, (4) 27876, (5) 37778 C, (6) 37778 D.

7. Fragment of crown 37778 E.

PLATE XVIII.

Figs. 1. Right antler, No. 27883.
2. Fragment of antler with pedicle, No. 27956.
3–8. Outlines of antler of *Cervus dama*, taken from Prof. Blasius's 'Fauna.'

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13. *On a* NEW SPECIES *of* DEER *from the* NORWICH CRAG.
By W. BOYD DAWKINS, Esq., M.A., F.R.S., F.G.S.

[PLATE XVIII. figs. 9–12.]

CONTENTS.

1. Introduction.	3. Measurements.
2. Description.	4. Determination.

1. *Introduction.*—The cervine antlers from the Crag and Forest-bed are so various in form, and for the most part so fragmentary, and the collections from the Miocene and Pliocene strata of France and Germany contain so many species of deer, that the utmost caution is necessary in establishing a new species. There is, however, one antler preserved in the British Museum, obtained by Mr. Wigham
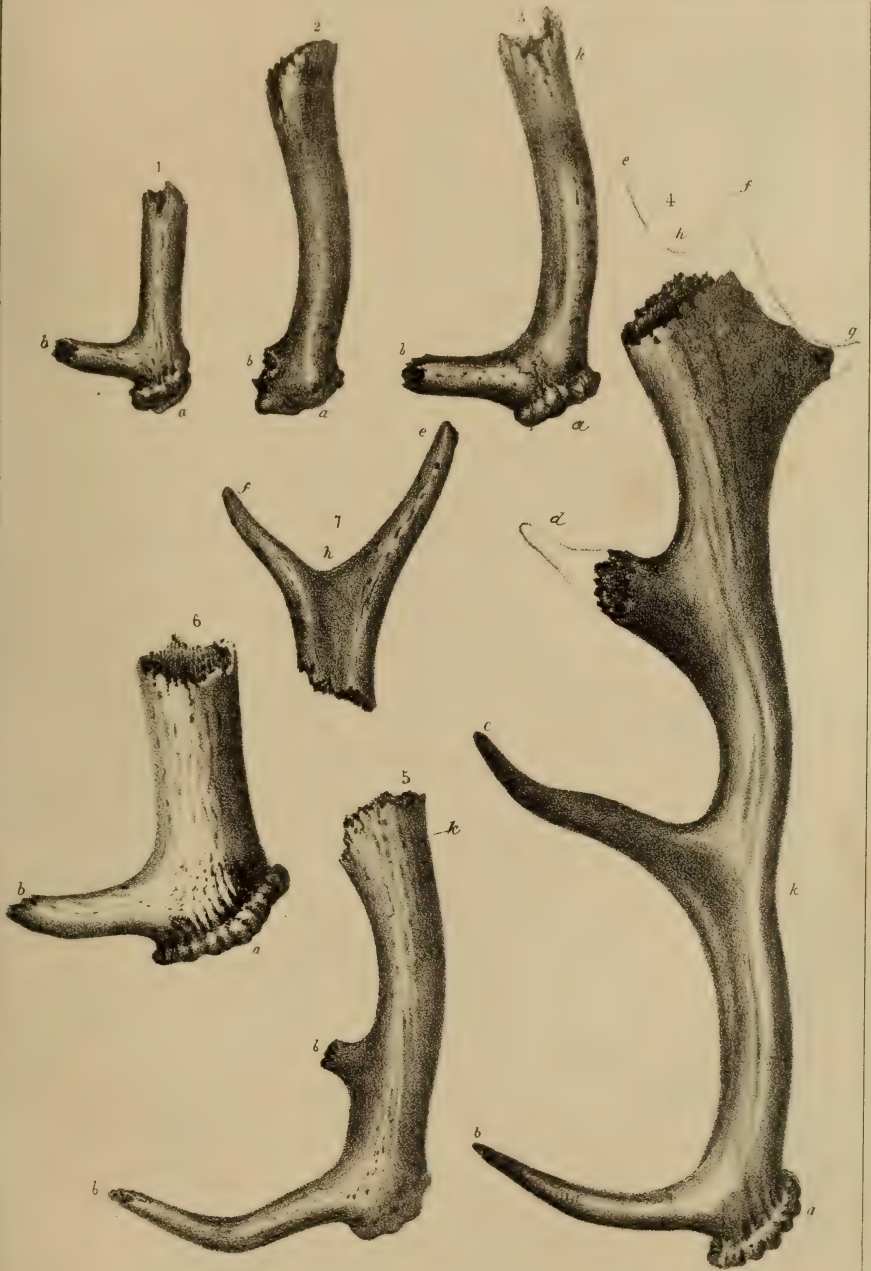
CERVUS BROWNI.

CERVUS BROWNI & C. FALCONERI

from the Norwich Crag, that in its remarkable form stands aloof from those hitherto known, and merits a careful examination. Dr. Falconer, prevented by his sudden death from following up the study of the Miocene and Pliocene antlers, has left behind sketches * of some of the more remarkable forms, which I have found of the greatest value in working at the Cervidæ. The antler in question did not escape his notice; and therefore I propose for it, in his memory, the specific name of *Cervus Falconeri.*

2. *Description.*—The antler (Pl. XVIII. figs 9, 10, 11) is a shed one of the left side, with its base slightly waterworn, and presenting a rounded section. There is no trace of a burr; but it may possibly have been worn away. The brow-tyne (*b*) is given off at a distance of 1·9 inch above the base, on the outer side, at a very obtuse angle to the basal part, and at right angles to the main body of the beam. At its point of junction with the beam it is oval in section; but it seems to recover the rounded form of the tyne of Fallow-deer, and of the closely allied species *Cervus Browni.* Its direction is obliquely downwards. The basal portion of the beam is put on at a very obtuse angle to the main body, and is hollowed and flattened at the point where the brow-tyne is given off. Immediately above it the beam becomes flattened both above and below, and especially at the points of origin of the bez-antler (*c*) and the third tyne (*d*). The former is small and of slightly oval section, and, like the brow-tyne (*b*), most probably ended in a round tip. The latter (*d*) is flattened, and presents an oval section; its basal measurement is about half as wide again as the palmated continuation of the beam. From *c* to *d* the beam gradually increases in width; from *d* upwards it is abruptly reflected and gradually decreases in size and thickness as far as the slightly upturned and fractured end, which latter, from its thinness, could not have been very far from the apex. The beam is smooth, possibly from being waterworn, but presents slight traces of broad and shallow grooves on its distal end. Its posterior boundary between the points of origin for the brow- and third tynes is almost straight. The second and third tynes (*c, d*) stand in such a relationship to the brow-antler (*b*), that the angle made by the plane passing through them with that of a plane passing through the latter and the basal part of the beam is almost a right angle, giving the appearance of the basal portion of the antler having been twisted a quarter of a turn downwards. There are also four other fragments of the basal portion of the antler that may be referred to this species—one in the British Museum, No. 35857, two in the magnificent collection of fossil mammalia made by Mr. Jarvis, of Cromer, and one from the Crag of Lowestoft. All are waterworn and from the Crag, and all repeat the characters that have been given in the description of the basal portion of the type specimen. They are, however, slightly smaller, and most probably belonged to younger individuals.

3. *Measurements.*—The following measurements in inches correspond with those of *Cervus Browni.*

* These are now deposited in the British Museum.

	Brit. Mus. 33507.
Basal circumference	3·8 in.
Distance of brow-tyne (*b*) above base	1·9
Length of beam between brow- (*b*) and bez- antler (*c*)	3·0
Breadth of bez-antler (*c*) at base............	0·8
Length of beam between bez-antler (*c*) and third tyne (*d*)	5·5
Breadth of third tyne (*d*)...................	1·7
Maximum length of the fragment	16·0
Circumference of beam above brow-tyne	3·8

4. *Determination.*—The characters presented by this antler are of very high specific value. First as regards the tynes. The brow-tyne is removed from the base, and in that respect differs from that of *Cervus dama* and *Cervus Brownii*. It is, moreover, situated in a different plane from that of the second and third tynes, and is so far closely akin to that of the French Pliocene *Cervus tetraceros* in the British Museum. The second tyne (*c*) is much smaller, and situated much nearer the first than in the Fallow-deer or *Cervus Brownii*; while the third, which strongly resembles that of the latter species, is further removed from the second, the relative positions of the two on the beam being reversed. The beam is flattened as in *C. tetraceros*, but not to so great a degree. The straightness of the beam differentiates it from the three species with which it has been compared, as well as from the Reindeer ; the smoothness, the absence of deep wrinkles, and the size, differentiate it from *C. tetraceros*. In fine, the antler presents a series of characters which are united in no fossil animal that has yet been discovered. Its flattened form and the development of the third anterior tyne cause its nearest fossil analogue to be the *Cervus Brownii* of Clacton, while among the living Cervidæ its nearest representative is the Fallow-deer. Its position in point of time, with respect to these two species, adequately represents its place in the zoological scale. It belongs to the class of flat-antlered deer represented by *Cervus dama*, with which it is connected through the medium of *Cervus Brownii*. The small amount of palmation exhibited by the antler of *C. Falconeri* is largely increased in *C. Brownii*, and reaches a maximum in *C. dama.*

DESCRIPTION OF PLATE XVIII. figs. 9–12.

Fig. 9. Upper view of antler of *Cervus Falconeri*, Brit. Mus. 33507.
    10. Lower   ,,   ,,
    11. Posterior   ,,   ,,
    12. Base of   ,,   ,,   Brit. Mus. 35857.

14. *Notes to* ACCOMPANY *a* SECTION *of the* STRATA *from the* CHALK *to the* BEMBRIDGE LIMESTONE *at* WHITECLIFF BAY, ISLE *of* WIGHT [*]. By T. CODRINGTON, Esq., F.G.S.

(Abridged.)

THE section is drawn from measurements made on the shore at low water during the autumn of 1867. In consequence of the dip of the beds being nearly vertical, the horizontal section exposed on the shore at low water is a section nearly at right angles to the stratification; and advantage was taken of favourable tides to measure a continuous section from the basement-bed of the London Clay to the Bembridge Limestone, always exactly at right angles to the strike of the beds.

The dip of the lower part, or the London Clay, is in a direction parallel to the line of the cliffs, so that the section exhibited in the cliff is at right angles to the beds; but the alteration in the direction of the dip, and in the line of the coast, both tend to make the section seen in the cliff more oblique in the higher beds; and in the Headon beds the obliquity is as much as 45°.

In bed VII [†]. of the Bracklesham series the junction of a bed of compact clay with a bed of shaly laminated clay was observed, which indicated a denudation of the laminated clay before the deposition of the compact clay on its edges.

No detailed examination of the fossils was attempted, except in the case of the Headon beds, where, at the suggestion of Mr. Jenkins (Assistant Secretary of the Geological Society), fossils were carefully sought for, in order to verify the opinion expressed by the Rev. O. Fisher in a note to his paper on the Bracklesham beds (Quart. Journ. Geol. Soc. vol. xviii. p. 67), to the effect that the equivalent of the remarkable Brockenhurst bed, which has been correlated by Von Könen with Dumont's Lower Tongrian formation of Belgium, occurs here near the bottom of the Middle Headon beds [‡].

The beds marked L and M in the section, which are those described in plate 4 of the Memoir of the Geological Survey of the Isle of Wight as "brown clay, abounding in marine shells," and "brown clay, with irregular fracture, shaly in places, with clayey nodules," are those referred to by Mr. Fisher.

A list of the shells [§] obtained from these beds, comprising upwards of 30 species, will be found on the section, and is appended to these notes. *Ostrea prona* and *Cardita deltoidea*, both distinctive Brockenhurst shells, are very abundant in bed L, and the latter occurs very frequently in bed M. The shells from bed M were all obtained from that part of the bed exposed only at low water spring tides.

The ironstone band P and the double band B will serve as guides

[*] The section referred to is deposited in the Society's Library.

[†] The beds distinguished by Roman numerals are the divisions described by the Rev. O. Fisher; those marked by Arabic numerals are in accordance with Mr. Prestwich's section.

[‡] See Pal. Soc. Mon. Brit. Foss. Corals, 2nd series, part 1. p. 40.

[§] I am indebted to the Rev. O. Fisher, Mr. Etheridge, and Mr. Jenkins for assistance in naming the shells.

to the intermediate beds, which may be found, even when hidden by sand, by measuring from the stone bands.

The *Bracklesham beds* are well exhibited on the shore. The bed of lignite, 6 feet thick, in Mr. Fisher's division V, is continuous for at least 200 feet. The clay below is penetrated by veins of the lignite, at first sight resembling the roots entering the underclay of a coal-seam, but on examination proving to be veins.

The *London Clay* is visible on the shore throughout its thickness of 299 feet.

The *Plastic Clay* was seen on the shore at intervals. Its thickness is about 200 feet, as measured on the $\frac{1}{2500}$ scale Ordnance Map.

Comparing the section at Whitecliff Bay with the section measured at Alum Bay by Mr. Bristow of the Geological Survey, it appears that the total thickness, from the Chalk to the base of the Fluviomarine series, is the same at both points, although the thicknesses of the component formations differ considerably.

	Thickness at Whitecliff Bay. feet.	Thickness at Alum Bay. feet.
Plastic Clay	200	84
London Clay	299	219
Lower Bagshot	142	660
Bracklesham and Barton	710	411
Upper Bagshot	158	122
	1509	1496
Headon...................................	168	181
	1677	1677

Fossils from the Headon Series.

BED L.

Avicula.
Ostrea prona (*S. V. Wood*).
Ostrea.
Cardium Laytoni?
Cardita deltoidea.
Corbula cuspidata.

Cytherea incrassata.
Cytherea.
Calyptræa trochiformis.
Fusus.
Voluta suturalis?
Lamna.

BED M.

Ostrea prona (*S. V. Wood*).
Cardium porulosum.
——— semigranulatum.
Cardita deltoidea.
Corbula cuspidata.
Nucula.
Psammobia compressa.
Sanguinolaria.
Tellina.
Cytherea incrassata.
——— suberycinoides.
Cytherea.
Buccinum labiatum.
Bulla elliptica?
Bulla.

Calyptræa trochiformis.
Cancellaria evulsa?
Conus dormitor (seminudus).
Pleurotoma plebeia.
Ditrupa.
Melania.
Fusus.
Natica labellata.
Natica.
Rostellaria rimosa.
Tornatella.
Lamna.
Graphiolaria Wetherelli.
Retepora.

15. *On the* GRAPTOLITES *of the* CONISTON FLAGS; *with* NOTES *on the* BRITISH SPECIES *of the* GENUS GRAPTOLITES. By HENRY ALLEYNE NICHOLSON, D.Sc., M.B., F.G.S.

[PLATES XIX. and XX.]

THE Silurian series of the north of England is composed of the following groups in ascending order:—1, the Skiddaw Slates; 2, the Green Slates and Porphyries; 3, the Coniston Limestone; 4, the Coniston Flags; 5, the Coniston Grits; and, 6, the Ludlow Rocks. Of these, the Skiddaw Slates contain a large and remarkable series of Graptolites, which are mostly identical with those of the Quebec group of America (see a paper by the author, Quart. Journ. Geol. Soc. vol. xxiv. p. 125). The Green Slates and Porphyries, and the overlying Coniston Limestone, with the exception of a fragment of a *Diplograpsus* from the former, have hitherto proved entirely barren of Graptolitic remains; and the same is true of the Ludlow group. The Coniston Flags, however, contain, as shown by Professor Harkness and myself, a very extensive and varied Graptolitic fauna, which it is the object of the present paper to describe.

As to the limits and age of the Coniston Flags, as well as their relation to the underlying limestone, considerable diversity of opinion exists, almost the only point in which all observers are agreed being that the Flags form a single natural group with the superjacent Grits. For my present purpose, however, it will suffice merely to indicate the different opinions which are held upon the subject. By Professor Sedgwick the Coniston Flags were held to be everywhere conformable to the Coniston Limestone; and he at first regarded them as of Wenlock age, a view which he subsequently modified so far as to refer them to the summit of the Lower Silurian division, whilst he placed the Grits at the base of the Upper Silurians. By Mr. Hughes, again, the Coniston Flags are believed to be unconformable to the Coniston Limestone, and to form, with the Grits, the base of the Upper Silurian series of the north of England (see Geol. Mag. vol. iv. p. 346). Lastly, it is believed by Professor Harkness and myself that the Coniston Flags include all the beds between the summit of the Coniston Limestone proper and the base of the Coniston Grits, that the flags are strictly conformable to the limestone, and that their age is Lower Silurian (see Quart. Journ. Geol. Soc. vol. xxii. p. 480 & vol. xxiv. p. 296).

Proceeding upon this last-mentioned view, the Coniston Flags are found to consist of the three following chief subdivisions in ascending order:—1, black mudstones or shales, occasionally almost anthracitic, alternating with unfossiliferous grey grits, which become more developed as we ascend; 2, cleaved flags, which are largely worked for industrial purposes; and, 3, "sheer-bate" flags, in which the cleavage and the bedding coincide with one another. The black mudstones or shales of the lowest subdivision are richly charged with Graptolites in a state of excellent preservation; and it is here that the greatest number of genera and species are found. To this portion of the series belong the Graptolite-beds of Mosedale

in Long Sleddale, of Skelgill Beck near Ambleside, and of Apple-tree Worth Beck near Broughton. The second subdivision, comprising the true "flags," is also rich in Graptolites; but these belong to few genera, and, owing to the prevalence of the cleavage, they are usually obtained with difficulty and in a state of bad preservation. The flags of Broughton Moor, in Furness, belong to this subdivision; but the Graptolites which they yield form a notable exception to the above statement, since they are usually preserved in the most exquisite relief. The third and highest subdivision, that of the "sheer-bate" flags, also contains a few Graptolites; but these are invariably very badly preserved, and I have not been able to determine with exactness the existence of more than a single species.

Looking at the Graptolites of the Coniston Flags as a whole, it will be seen from the following list that the great majority of the species are Lower Silurian, there being, however, a small admixture of Upper-Silurian forms in the upper two subdivisions of the series. The Graptolites of the lowest subdivision, with the exception of *Graptolites priodon*, are entirely Lower-Silurian species, and all, except those now described for the first time, are familiar as occurring in the Upper Llandeilo rocks of the south of Scotland. In justification of this statement it is simply necessary to quote the well-known names of *Diplograpsus pristis*, His., *D. palmeus*, Barr., *Climacograpus teretiusculus*, His., *Rastrites peregrinus*, Barr., *Graptolites Sedgwickii*, Portl., *G. sagittarius*, Linn., *G. Nilssoni*, Barr., &c. The total absence, as far as is yet known, of the genus *Didymograpsus*, so common in the Graptolitiferous rocks of Dumfriesshire, is noticeable, as well as the presence of *Rastrites Linnæi* and *R. peregrinus*, for the first time found in Britain in strata younger than the Upper Llandeilo. In the second subdivision, comprising the flags of Broughton Moor, four species are all that I have been able to make out satisfactorily, viz. *Graptolites Sedgwickii*, Portl., *G. priodon*, Bronn, *G. colonus*, Barr., and *Retiolites Geinitzianus*, Barr. Of these, *G. Sedgwickii* is the only one which can be used for purposes of classification, it being a familiar Lower-Silurian fossil in Britain. The remaining three are as much Upper as Lower Silurian forms, *G. priodon* ranging from the Upper Llandeilo to the Ludlow rocks inclusive, whilst *Retiolites Geinitzianus* is usually quoted as a Wenlock species. In the "sheer-bate" beds at the top of the series there occurs only one species which can be accurately made out; and this is apparently identical with *G. colonus*, Barr. I may mention that this same species passes up into the Coniston Grits, this and *G. priodon* being apparently the only survivors, in the Grits, of the rich Graptolitic fauna of the Flags, *G. sagittarius* being a doubtful exception.

The following list of the *Graptolites* of the Coniston Flags is derived entirely from specimens collected by myself, with the exception of the examples from the flags of Broughton Moor, for which I am indebted to Mr. Morris of Ulverstone.

It will be seen that there are altogether twenty-four species, of

which five are new, whilst the remainder have all been previously described. Of these latter, however, *Graptolites turriculatus*, Barr., *G. Bohemicus*, Barr., *Diplograpsus angustifolius*, Hall, *D. putillus*, Hall, and *Retiolites Geinitzianus*, Barr., are now for the first time fully described from British specimens.

List of the Graptolites of the Coniston Flags.

Climacograpsus (Diplograpsus) teretiusculus, *His.* Mosedale in Long Sleddale, and Skelgill Beck.
Diplograpsus angustifolius, *Hall.* Skelgill Beck.
—— confertus, *Nich.* Skelgill Beck.
—— folium, *His.* Skelgill Beck.
—— palmeus, *Barr.* Skelgill Beck.
—— pristis, *His.* Mosedale in Long Sleddale.
—— putillus, *Hall.* Skelgill Beck.
—— tamariscus, *Nich.* Skelgill Beck.
—— vesiculosus, *Nich.* Skelgill Beck.
Graptolites Bohemicus, *Barr.* Skelgill Beck.
—— colonus, *Barr.* Torver Beck, Horton in Ribblesdale, Broughton Moor, &c.
—— discretus, *Nich.* Mosedale and Skelgill Beck.
—— fimbriatus, *Nich.* Skelgill Beck.
—— lobiferus, *M'Coy.* Skelgill Beck.
—— Nilssoni, *Barr.* Skelgill Beck and Mosedale.
—— priodon, *Bronn.* Skelgill and Broughton Moor.
—— Sedgwickii, *Portl.* Mosedale, Skelgill Beck, and Broughton Moor.
—— sagittarius, *Linn.* Mosedale and Skelgill Beck.
—— tenuis, *Portl* (?). Skelgill Beck.
—— turriculatus, *Barr.* Mosedale in Long Sleddale.
Rastrites Linnæi, *Barr.* Mosedale.
—— peregrinus, *Barr.* Skelgill Beck.
Retiolites Geinitzianus, *Barr.* Broughton Moor.
—— perlatus, *Nich.* Mosedale in Long Sleddale.

DIPLOGRAPSUS PALMEUS, Barr.* Pl. XIX. figs. 1–3.

> *Graptolithus palmeus*, Barrande, Grapt. de Bohême, pl. 3. figs. 1–4 & 7.
> *Diplograpsus palmeus*, Geinitz, Graptolithen, Taf. 1. figs. 5–15.
> —— *foliaceus*, Murchison (?), Sil. Syst. pl. 26. fig. 3.

Frond from less than $\frac{1}{2}$ to more than 1 inch in length, exclusive of the distal prolongation of the axis; celluliferous on the two sides, and attaining a width of from $\frac{1}{10}$ to $\frac{1}{5}$ of an inch. The base is formed by a broad, obtuse, and truncated radicular process, the point of which usually presents the appearance of having been broken off proximally, whilst it is prolonged distally into the first two cellules. The form of the frond, though variable, is highly characteristic. In most specimens the widest portion of the frond is immediately above the base, about the level

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* The species here described under this name is identical with that figured as *D. pristis*, His., in the third edition of 'Siluria' (see Foss. xi. fig. 4), and figured as *D. folium*, His., in the last edition of the same. If this is really the *D. folium* of Hisinger, then this name has the priority over *D. palmeus*, Barr.; but I am not in a position to refer to the original work, and am therefore unable to decide this point.

of the fourth or fifth cellule, a gradual though slight contraction then taking place, and continuing up to the distal extremity. In other specimens, again, the frond is more decidedly fusiform, or lanceolate-ovate, the cellules attaining their full maturity from about $\frac{1}{6}$ to $\frac{1}{4}$ of an inch above the base ; whilst in others the shape is simply ovate, the broadest part in all being just above the base. The distal extremity, in the most unequivocal specimens, is terminated by a straight non-celluliferous line. The axis is very delicate, and is usually prolonged beyond the distal extremity of the frond, this distal extension being often somewhat dilated. The common canal, though very narrow, is undoubtedly present. The cellules average 30 in the space of an inch, but vary between 25 and 40 ; they are inclined to the axis at an angle of from 30° to 45°, differing in different parts of the frond, are in contact for about two-thirds of their entire length, narrow at their origin from the common canal, but widening out gradually towards the aperture, and, when well preserved, marked in their outer half by numerous fine striæ or lines of growth which run parallel to the cell-mouths. The cell-mouths are curved, and nearly at right angles to the axis of the cellules, their lower lips being very usually prolonged into acute submucronate tips, but not furnished with true spines. These submucronate denticles are not observable in the figures of Barrande and Geinitz, but they are present in most of our English specimens. That their presence or absence is not, however, of specific importance, but is chiefly due to the state of preservation, is shown by the fact that they are sometimes present in one portion and absent in another of even the same specimen.

The above characters, drawn chiefly from Dumfriesshire specimens, combine to make up a very distinct species, which appears on the whole to agree in all important points with the *Graptolithus palmeus* of Barrande. The specimens from the Coniston Flags, though differing in some minor particulars, cannot possibly be separated from the above, as they agree in the possession of a blunt, tapering radicular process, and in the very peculiar shape of the frond. The cellules, too, have the same shape, and the same submucronate extensions from their lower margins ; but their number is usually more than 40 in the space of an inch, and the entire frond, as far as I have seen, does not attain a length of more than half an inch, exclusive of the axis.

Loc. Coniston Flags of Skelgill Beck, near Ambleside. (Also common and well preserved in certain localities in the Upper Llandeilo rocks of Dumfriesshire.)

DIPLOGRAPSUS FOLIUM, His.   Pl. XIX. figs. 4–7.
　　Prionotus folium, Hisinger, Leth. Suec. Supp. t. 35. fig. 8.
　　Graptolithus ovatus, Barrande, Grapt. de Bohême, pl. 3. figs. 8, 9.

Frond ovate, commencing at the base by a broad tapering truncated radicular process, which is prolonged upwards into the first two cellules. Length from $\frac{2}{10}$ to $.\frac{3}{10}$ of an inch; breadth

nearly $\frac{1}{5}$ of an inch. Axis capillary, sometimes prolonged beyond the distal extremity of the frond. Common canal narrow. Cellules inclined to the axis at about 40° in the middle of the frond, but becoming nearly vertical towards its distal extremity, the last cellules being nearly parallel with the axis. The cellules are in all respects similar to those of *D. palmeus*, Barr., being narrow at their origin from the common canal, but widening out towards the cell-aperture, slightly curved, and marked in their outer half with numerous fine curved striæ running parallel with the cell-apertures. Most specimens exhibit from 40 to 50 cellules in the space of an inch, so that the smaller examples do not contain more than 10 cellules on each side.

The above description is drawn from several specimens which I obtained from the Coniston Flags; and though differing in some respects from what has been usually figured as *D. folium*, His., I am unable at present to place them under any other species. At the same time I am strongly of the opinion that (whichever name may be ultimately retained) *D. folium*, His., will eventually turn out to be nothing more than a variety or a young form of *D. palmeus*, Barr., most probably the latter. The two agree exactly in the shape of the cellules and in the characters of the radicular process; whilst the only difference of any moment is to be found in the fact that *D. folium*, His., terminates distally in a rounded celluliferous margin, while *D. palmeus*, Barr., has the same extremity bounded by a straight non-celluliferous line. *Graptolithus ovatus* of Barrande, appears also to be a young form of *D. palmeus*, and it is, at any rate, inseparable from what I have here described as *D. folium*, His.

Loc. Coniston Flags of Skelgill Beck, near Ambleside.

DIPLOGRAPSUS ANGUSTIFOLIUS, Hall. Pl. XIX. figs. 8, 9.
     Graptolithus angustifolius, Hall, Pal. N. York, vol. iii. p. 515.

Frond simple, and diprionidian. Breadth a little short of one line. Cellules from 28 to 30 in the space of an inch, subalternate, or nearly opposite to one another, " the denticles short, ovate-acute, the extremities sometimes subobtuse" (Hall). The common canal is very slender, and the axis is prolonged beyond the distal extremity of the frond. According to Hall, the base " is marked by minute setiform radicles."

I have found one example of this species, exquisitely preserved in relief, in the Graptolitiferous mudstones of Skelgill Beck, and there can be no question of its identity with the American form. As *D. angustifolius*, Hall, has been recently confounded with *D. acuminatus*, Nich. (Carruthers, Geol. Mag. vol. v. p. 130), I may here mention that no two species of the genus *Diplograpsus* are separated from one another by better-marked distinctions. In *D. angustifolius*, Hall, the base is marked by " minute setiform radicles" (one or more in number), whilst the cellules are subalternate, are from 28 to 30 in the space of an inch, and possess extremities which are usually rounded off and obtuse. In *D. acuminatus*, Nich., on

the other hand, the base consists of a long and tapering radicle, which "gradually becomes continuous with the body of the stipe," whilst the cellules are not more than from 20 to 25 in the space of an inch, are markedly alternate, and terminate in "toothed and angular denticles" (see Geol. Mag. vol. iv. p. 109).

Loc. Coniston Flags of Skelgill Beck, near Ambleside.

DIPLOGRAPSUS CONFERTUS, Nich. Pl. XIX. figs. 14, 15.

Frond in short fragments, tapering towards the base, and about $\frac{1}{3}$ of an inch wide in the fully developed portion. Total length unknown, neither the proximal nor the distal extremities of the frond being exhibited. Cellules from 50 to 60 in the space of an inch, inclined to the axis at an angle of about 45°, the cell-apertures being horizontal or directed slightly upwards. The apices of the cellules are prolonged into long, slender, submucronate tips, though they can hardly be said to be furnished with distinct spines.

Though the above is only known to me by numerous short fragments, and though the characters of the base are nowhere exhibited, I have been compelled to frame a new species for its reception, as I am unable to make it agree with any form as yet described. In the shape of the denticles it agrees very closely with *D. mucronatus*, Hall, and it also presents a certain resemblance to *D. palmeus*, Barr.; but it is at once distinguished from both these species by the very great number of cellules in the space of an inch. It is also easily separated from *D. mucronatus*, Hall, by the great comparative width of the frond.

Loc. Common in the Coniston Flags of Skelgill Beck.

DIPLOGRAPSUS TAMARISCUS, Nich. Pl. XIX. figs. 10–13.

Frond diprionidian, slender, of unknown length, and having a breadth of about $\frac{1}{25}$ of an inch a little above the base. The base is pointed, and sometimes is provided with a proximal extension of the axis. The common canal is well marked, but is exceedingly narrow. The cellules are from 25 to 30 in the space of an inch, alternating very distinctly with one another on the two sides of the frond, free for more than two-thirds of their entire length, inclined to the axis at about 10°, and having their outer margins more or less convex and gibbous. The cell-mouths are at right angles to the axis, or nearly so, and occupy about one-half of the entire breadth of the frond. In specimens preserved in relief, the test appears to be marked with fine transverse striæ.

This pretty little *Diplograpsus* is readily distinguished by its small width and pointed base, and by the alternate, curved, cup-shaped cellules, which leave scarcely any common canal, are inclined to the axis at an extremely small angle, and possess nearly horizontal apertures. I have named it after *Sertularia tamarisca*, to branchlets of which it presents a considerable resemblance. The specimens in my possession, from the Coniston Flags, are all fragments in the neighbourhood of the base; but I possess more perfect examples from the Upper Llandeilo rocks of Dumfriesshire.

Loc. Coniston Flags of Skelgill Beck (also in the Upper Llandeilo shales of Duffkinnel Burn, near Wamphray).

DIPLOGRAPSUS PUTILLUS, Hall, sp.   Pl. XIX. figs. 17, 18.

> *Graptolithus putillus*, Hall, Grapt. Quebec Group, p. 44, pl. A.
> figs. 10–12.

Frond diprionidian, about $\frac{1}{2}$ inch in length and 1 line in breadth. Base apparently pointed. The frond forms a cylindrical tube, divided into two vertical compartments by a longitudinal septum, the lateral edges of which appear on the exterior of the test as two gently undulating lines between the rows of cellules. The common canal is, comparatively speaking, very wide. The cellules are about 25 in the space of an inch, very narrow, curved, with the convexities directed outwards, forming an angle of 10°, or thereabouts, with the axis, and free for almost their entire length. The cell-mouths are rectangular to the direction of the cellules, or rather more than rectangular to the axis.

This exceedingly distinct species was described by Hall from the Hudson-River group of Iowa, and I have now found two specimens, the first discovered in Britain, in the Coniston Flags of Westmoreland. It is at once recognized by the breadth of the common canal, and by the narrow, curved, nearly vertical cellules, which hardly overlap one another at all, and possess cell-mouths which are more than rectangular to the axis.

Loc. Coniston Flags of Skelgill Beck, near Ambleside, beautifully preserved in relief.

DIPLOGRAPSUS VESICULOSUS, Nich.

I have obtained a single fragment of this truly extraordinary species, from the Coniston Flags of Skelgill Beck. Its characters, however, are so anomalous that I shall reserve all description of it for a future occasion, as it would occupy too much space in the present paper. I merely mention it here to point out that it does not possess a single character in common with *D. pristis*, His., of which it has been asserted to be merely a variety. (See Carruthers, Geol. Mag. vol. v. p. 130.)

DIPLOGRAPSUS PRISTIS, His.

> *Prionotus pristis*, Hisinger, Leth. Suecica, t. 35. fig. 5.
> *Diplograpsus minutus* (vel *minimus*), Carruthers, Geol. Mag.
> vol. v. pl. 5. fig. 12.

Frond diprionidian, varying in length from a quarter of an inch to nearly 3 inches, exclusive of the distal prolongation of the axis, which often adds another inch to the total length. The breadth in the fully developed portion varies from $\frac{1}{8}$ to $\frac{1}{5}$ of an inch. The general shape of the frond is extremely characteristic, being narrow at the base, and widening out gradually and regularly until the full width is attained. This point may be reached in the lower third, in the centre, or not till towards the distal extremity; and when it has been once attained, the frond either contracts slightly or continues of the same breadth to the end. The proximal extremity or base is small and rounded, and is furnished with three radicular pro-

cesses, which are usually small and short.   The central one of these
is the proximal extension of the solid axis, and constitutes the true
"radicle" or "initial point."   The two lateral spines are processes
from the first two cellules on either side, and point downwards,
diverging from the line of the axis at an acute angle.   The distal
extremity is truncated, and is limited by a straight line, beyond
which the solid axis is prolonged, often for an inch or more, being
sometimes slightly dilated.   (This dilatation of the distal extremity
of the axis must be carefully distinguished from that of *D. vesicu-
losus*, Nich., in which it is much more extensively developed, whilst
the other characters of the frond are entirely different.)   The cel-
lules are from 20 to 28 in the space of an inch, inclined to the axis
at from 40° to 45°, overlapping one another for about one-half of
their length, and terminating in broad triangular denticles, usually
somewhat rounded at the point.   The cell-apertures are at right
angles to the axis, or directed slightly upwards, each transgressing
for a short distance upon the cellule immediately above.

The above description is taken mostly from specimens obtained
from the Upper Llandeilo rocks of Dumfriesshire ; but the examples
from the Coniston Flags do not differ in any important respect,
though mostly fragmentary and but indifferently preserved.   *D.
pristis*, His., is easily recognized by the peculiar shape of the frond,
by the three small processes at the base, and by the characters of
the cellules.   *D. palmeus*, Barr., has not unfrequently been con-
founded with it ; but the diagnosis between the two is extremely
easy when the above characters are attended to.

Loc. Coniston Flags of Mosedale in Long Sleddale.

CLIMACOGRAPSUS (DIPLOGRAPSUS) TERETIUSCULUS, His.

> *Prionotus teretiusculus*, Hisinger, Leth. Suec. Supp. ii. t. 38.
>   fig. 4.
> *Graptolites personatus*, Scharenberg, Ueber Grapt. t. 2. figs.
>   17–32.
> *Diplograpsus rectangularis*, M'Coy, Ann. Nat. Hist. 2nd series,
>   vol. vi. p. 271, and Pal. Foss. p. 8, pl. 1. B. fig. 8.
> *Climacograpsus scalaris*, Carruthers, Geol. Mag. vol. v. p. 131.
> *Climacograpsus minutus*, Carruthers, ibid. p. 132.

Frond forming a hollow cylinder, divided into two tubes by a ver-
tical septum, and having a row of cellules excavated in its sub-
stance on each side.   The frond is thus seen to be composed of
two simple monoprionidian stipes united back to back, the dorsal
walls of the two coalescing to form the median septum, along the
centre of which runs the solid axis.   The general form of the frond is
cylindrical, varying in length from $\frac{1}{4}$ of an inch up to $2\frac{1}{2}$ inches (ex-
clusive of the prolongations of the axis), tapering towards the base,
and attaining a width of $\frac{1}{8}$ of an inch in the fully developed portion
of an adult specimen.   The solid axis is prolonged beyond both extre-
mities of the frond, often to a very considerable length.   The ap-
pearances presented by different examples vary according to the

mode of preservation, the direction in which compression has been effected, and the particular view which is afforded by any given specimen.

When compressed from side to side, or at right angles to the cellules, the cell-mouths appear as quadrangular or oblong notches, rounded at the base, and extending into the body of the stipe, the external terminations of the apertures being on a level with the outer margins of the frond. About 30 of these notches occupy the space of an inch. This form is the one which was described by Prof. M‘Coy under the name of *Diplograpsus rectangularis*. When compressed from back to front, the cell-mouths appear as oval-oblong, sometimes linear, sometimes lunate, apertures, at right angles to the direction of the frond, and about 30 in the space of an inch. According as the compression has been directly from back to front, or according as more or less of the lateral surface is exhibited, will the apertures of one or both rows of cellules be partially or entirely displayed, the variations in this respect being numerous.

When preserved in the round, and viewed from side to side, the septum between the two simple stipes which together form the frond exhibits its lateral margin as an " impressed median line, which is generally straight, but is sometimes a little wavy between the cells" (Salter). The variations in this species are so numerous, its structure is so remarkable and withal so readily interpreted, and it throws so much light upon the nature of Graptolites in general, that I shall content myself for the present with the above brief description, reserving a more detailed account for a paper which I am preparing upon the British species of *Diplograpsus* and *Climacograpsus*. There are, however, two abnormal appearances which I may notice here, as they are exhibited by specimens which I have obtained from the Coniston Flags. The first of these consists in the attachment to the proximal extension of the solid axis of several small, apparently vesicular bodies which occur on both sides of the axis, and are also attached to the margins of the frond itself near the base. The second consists in the occurrence of a form of *Diplograpsus* displaying plain margins, with a filiform central axis, and with no indication of cell-apertures beyond a slight crenation of the margins. These specimens, at first sight very puzzling, I have determined to be really *Climacograpsus teretiusculus* split in half, so as to present to view nothing but the vertical septum which divides the frond, and along the centre of which the axis runs. The correctness of this view is established by the examination of a specimen shown partially in relief and partially as an impression, the former portion exhibiting the characters above mentioned, whilst the latter displays transverse cell-apertures.

Loc. Very common, and beautifully preserved in relief in the Coniston Flags of Skelgill Beck, near Ambleside; also, as impressions only, in the flags of Mosedale in Long Sleddale.

Genus RETIOLITES, Barr.

Frond diprionidian, linear, with subparallel margins. The cel-

lules are in contact throughout their entire length, and arise from a single, internal, cœnosarcal canal, which " occupies the central portion of the stipe." A solid axis is sometimes present, but appears to be absent in some species. The test is reticulate, or punctate. According to Barrande and Hall, the section of the frond shows that it is triangular in shape; but in the specimens from the Coniston Flags (all beautifully preserved in relief) the frond is shown to have the form of a flattened cylinder, elliptical in transverse section, the flattening not seeming to be in any way due to compression, since it is invariably in a direction at right angles to that of the cellules.

RETIOLITES GEINITZIANUS, Barr. Pl. XIX. figs. 19, 20.

> *Gladiolites Geinitzianus*, Barrande, Grapt. de Bohême, pl. 4. figs. 16–33.

Frond known by fragments only, which show neither the proximal nor the distal extremity. The breadth of the frond in its widest portion is from $\frac{3}{20}$ up to $\frac{3}{15}$ of an inch, gradually diminishing towards the base. The cellules are disposed on each side of a common canal, there being apparently no solid axis. They are in the form of quadrangular tubes arranged alternately along opposite sides of the frond, in contact throughout their entire length, from 25 to 30 in the space of an inch, and forming an angle of about 60° with the general axis of the frond. The cellules do not meet in the centre, but leave a vacant median space, into which the cell-partitions do not enter. The cell-mouths are nearly in a line, subparallel as regards the median line of the frond, and forming an angle of about 120° with the inferior cell-walls. The test is covered with small, rounded, often umbilicated reticulations.

Loc. Coniston Flags of Broughton Moor in Furness.

RETIOLITES PERLATUS, Nich. Pl. XIX. figs. 21, 22.

Frond attaining a width in the fully developed portion of not less than $\frac{1}{4}$ of an inch. The total length, though unknown, must have been very considerable, as one of my specimens reaches a length of 2 inches without showing any signs of contracting towards either extremity. The cellules are in contact throughout out their entire length, the cell-mouths being slightly convex, and parallel with the median line of the frond. The cell-partitions are very faintly marked. There are plain indications of a very delicate solid axis. The entire impression is crossed in every direction by interlacing reticulated threads, which leave numerous small lacunæ or interspaces between them.

This extraordinary Graptolite, in the venose character of its reticulation, is undistinguishable from *Retiolites venosus* of Hall (Pal. N. York, vol. ii. p. 40, pl. A. xvii. fig. 2). It differs, however, in apparently wanting the emarginate lateral borders and the mucronate extensions of the cell-partitions which distinguish the latter; and it is even more readily separated by its comparatively gigantic

size, its breadth being nearly three times as great as that of the species figured by Hall. I am, however, bound to admit, with the imperfect materials at present in my hands, that I regard the separation of *R. perlatus* as a distinct species as simply provisional, since more complete specimens might show that it is a large form of *R. venosus*, Hall. It is only known to me by a few fragments from the Upper Llandeilo rocks of Dumfriesshire, and by two specimens which I obtained at the base of the Coniston Flags, not 10 feet above the Coniston Limestone. Hall's *R. venosus*, on the other hand, is from the Clinton group, of Middle-Silurian age. The occurrence of *R. perlatus* in the Graptolitiferous mudstones at the base of the Coniston Flags is of importance as serving to connect these beds with the flags of Broughton Moor, which are much higher in the series and contain *R. Geinitzianus*. Its association, too, with so many unimpeachable Lower-Silurian forms is noteworthy as showing that the genus is in no way characteristic of the Upper-Silurian period. Lastly, it is of interest as corroborating the statement of Hall, that a solid axis is present in some, if not in all the species of *Retiolites*.

Loc. Coniston Flags of Mosedale in Long Sleddale. Rare in the Upper Llandeilo rocks of Duffkinnel, near Wamphray.

RASTRITES PEREGRINUS, Barrande. Pl. XIX. figs. 23, 24.

Stipe consisting of a simple linear tube, from which the cellules are given off more or less nearly at right angles. The proximal and distal extremities are unknown, the specimens hitherto discovered being short fragments, usually curved. The cellules vary in number from 22 to 40 in the space of an inch, and from $\frac{1}{10}$ to $\frac{1}{8}$ of an inch in length. In shape they are linear, slightly narrower at their origin from the axial tube than towards their distal extremities, and usually impressed longitudinally with a median line.

The specimens of *Rastrites peregrinus* from the Coniston Flags present all the characters of the ordinary form. Their occurrence in this formation, along with the cognate *R. Linnæi*, is somewhat noteworthy, no member of the genus, as far as I am aware, having ever before been found in Britain in rocks younger than the Upper Llandeilo.

Loc. Coniston Flags of Skelgill Beck, near Ambleside.

RASTRITES LINNÆI, Barrande. Pl. XIX. figs. 25, 26.

Stipe of unknown length, usually gently curved, and consisting of a delicate axial tube, giving off long tubular cellules from one side. The axial tube is hair-like, and of greater tenuity, when compared with the size of the cellules, than, perhaps, in any other species of the genus. The cellules are nearly rectangular to the axis, or are directed slightly upwards, from 8 to 12 in the space of an inch, from $\frac{1}{10}$ to more than $\frac{1}{8}$ of an inch in length, linear, slightly enlarged at their commencement, and tapering gradually to their termination.

R. Linnæi is a Bohemian species, the characters of which are very distinct, being at once recognized by the long, remote cellules, and

the delicate common tube.   It was found by Prof. Harkness, some years ago, in the Upper Llandeilo rocks of Dumfriesshire, at Duff-kinnel Burn near Wamphray, and it forms, therefore, another of the many Dumfriesshire species which are found also in the Conis-ton Flags.

Loc. Coniston Flags of Mosedale in Long Sleddale.

Genus GRAPTOLITES, *vel* GRAPTOLITHUS, Linn.

In describing the species of the genus *Graptolites* there are some terms which it is as well to define beforehand.   Theoretically each cel-lule may be looked upon as a cylindrical tube, possessing in longitudi-nal section four borders.   Of these, the "*inner*" is not defined, as it forms the base of the cellule, and rests upon the common canal; the "*outer*" border forms the cell-mouth; the "*inferior*" margin is that which bounds the cellule proximally or towards the base; and the "*superior*" is that which forms the distal limit.   In many species, such as *G. sagittarius*, Linn., all these are present.   In some Graptolites, however, the superior margin of the cellule may be said to be practically absent, as in *G. Nilssoni*, Barr., and *G. discretus*, Nich., since in these cases the cellules are triangular, and the com-mon canal is the limit along both the inner and the superior mar-gins.   In others, again, as in *G. Sedgwickii*, Portl., the cellule ter-minates in a pointed apex, so that the outer margin can hardly be said to form a distinct line.

GRAPTOLITES LOBIFERUS, M'Coy.   Pl. XIX. figs. 27–30.

> *G. lobiferus*, M'Coy, Ann. & Mag. Nat. Hist. 2nd series, vol. vi. p. 270, and Pal. Foss. pl. 1. B. fig. 3.
>
> *G. Becki*, Barr. Grapt. de Bohême, pl. 3. figs. 14–18.
>
> *G. Nicoli*, Harkness, Quart. Journ. Geol. Soc. vol. vii. pl. 1. figs. 5 *a*, *b*.
>
> *G. Clingani*, Carruthers, Geol. Mag. vol. v. pl. 5. figs. 19 *a*, *b*.

Stipe linear, monoprionidian, often of great length, and attaining a breadth of from $\frac{1}{12}$ to $\frac{1}{10}$ of an inch in the fully grown por-tion.   Axis slender and hair-like.   Common canal broad and well marked.   Cellules nearly rectangular to the axis, but having a slight upward inclination; their upper margins curved, termina-ting in "obtusely rounded lobes," in which "a notch on the un-der edge separates the rounded extremity from the oblique descend-ing margin" (M'Coy).   The cellules in the fully developed portion of the stipe vary between 12 and 30 in the space of an inch, the average in the Dumfriesshire specimens being from 16 to 18, whilst in the examples from the Coniston Flags it is from 20 to 30.   The base or proximal extremity is slender and curved, the common canal having a great comparative width (see Pl. XIX. fig. 29); the cellules are from 20 to 25 in the space of an inch, and are much narrower than those in the adult portion of the stipe, coming to bear a considerable resemblance to the cells of *G. Sedgwickii*, Portl.   The cell-mouth, as is occasionally well shown, opens at the notch in the under mar-gin of the cellule (Pl. XIX. fig. 30).

Though the typical form of *G. lobiferus*, M'Coy, can be readily distinguished by the above characters, yet it must be conceded that it in some cases approaches so closely to *G. Sedgwickii*, Portl., as to render any sharp line of demarcation between the two impossible. This is especially the case in specimens showing fragments of the stipe near the base, in which case an exact distinction is sometimes impossible. *Graptolites millipeda*, of M'Coy, does not seem to have been founded on the proximal extremity of *G. lobiferus*, as has been thought, but upon that of *G. Sedgwickii*. *G. Clingani*, Carr., is, however, to be referred to the young form of *G. lobiferus*, there being in this case a distal extension of the axis, as there usually is in the young of the monoprionidian species. The specimens of *G. lobiferus* from the Coniston Flags agree in almost all respects with those from Dumfriesshire; but the cellules seem to be generally rather more closely set.

Two varieties of *G. lobiferus* appear to be sufficiently well-marked to deserve distinct names.

Var. α. NICOLI, Harkn. Quart. Journ. Geol. Soc. vol. vii. pl. 1. figs. 5 *a*, *b*.

This form approaches very closely to the normal type, the chief points of difference being the horizontality of the cellules, and their tolerably uniform breadth, the extremities not forming " obtusely rounded lobes." The number of the cellules is also higher than is usual in the ordinary form, being from 25 to 30 in the space of an inch. This variety occurs commonly in some parts of the Coniston Flags, and seems to be really a variety and not to depend upon the mode of preservation, direction of the pressure, or any other accidental circumstance.

Var. β. EXIGUUS, Nich.   Pl. I. figs. 27, 28.

This is the form figured by Barrande as the young of *G. lobiferus* (*op cit*. pl. 3. fig. 14). It is distinguished by its narrow width (not more than from $\frac{1}{25}$ to $\frac{1}{20}$ of an inch), by the very slender common canal, and by the shape of the cellules, which have an upward inclination, are slender at the base, and have the extremity inrolled so as to form a rounded knob. The cellules are about 30 in the space of an inch.

Loc. The ordinary form of *G. lobiferus* occurs in the Coniston Flags of Skelgill Beck, near Ambleside, and of Mosedale in Long Sleddale; whilst the former locality yields also the two varieties above described.

GRAPTOLITES SEDGWICKII, Portl.   Pl. XIX. figs. 31–34, Pl. XX. figs. 1, 2, and 28.

> *G. convolutus*, Hisinger, Leth. Suec. t. 35. fig. 7.
> *G. proteus*, Barrande, Grapt. de Bohême, pl. 4. figs. 12–15.
> *G. distans*, Portlock, Geol. Rep. pl. 19. figs. 4 *a*, 4 *b*.
> *G. spiralis*, Geinitz, Graptolithen, pl. 4. figs. 32–35; Barrande, *op. cit.* pl. 3. figs. 10–13.

G. *millipeda*, M'Coy, Pal. Foss. pl. 1. B. fig. 6.

Rastrites triangulatus, Harkness, Quart. Journ. Geol. Soc. vol. vii. pl. 1. figs. 3 *a–d*.

G. *Clintonensis*, Hall, Pal. N. York, vol. ii. pl. 17. A. figs. 1 *a–i*.

G. *convolutus*, Carruthers, Geol. Mag. vol. v. pl. 5. fig. 1.

No Graptolite, probably, is more protean in its form and presents greater variations than does G. *Sedgwickii*, Portl. Many of these differences are, doubtless, due to the mode of preservation, or to the age of the individual; and others may possibly be of sexual value; but two varieties at any rate appear to be sufficiently well defined to warrant us in giving them distinct names. Whilst some of the forms under which G. *Sedgwickii* appears approach closely to G. *lobiferus*, M'Coy, others, again, make an approximation to G. *Nilssoni*, Barr., whilst a third group shows a tendency to approach the genus *Rastrites*. At the same time all the varieties graduate into one another by a series of closely connected forms, so that only the typical examples of each admit of being accurately placed. Further, three species (viz. G. *convolutus*, His., G. *proteus*, Barr., and G. *millipeda*, M'Coy) have been founded upon the slender curved base of G. *Sedgwickii*; and a fourth, G. *spiralis*, Gein., has been formed from specimens of the same, in which the entire frond is rolled up into a spiral, the coils of which lie in one plane. It will be evident, then, that the examination of G. *Sedgwickii*, and the discrimination of its various forms, is beset with unusual difficulty, and that specimens will be constantly presenting themselves which it will be impossible to assign with certainty to any recognized variety.

The ordinary form of G. *Sedgwickii*, as described by Portlock, and as figured by M'Coy, consists of a simple monoprionidian stipe of considerable but unknown length. The breadth of the adult portion of the stipe from the solid axis to the cell-mouths is from one to two lines. The axis is capillary; and the common canal is broad and conspicuous, sometimes attaining a width of nearly $\frac{1}{20}$ of an inch. The cellules are long, slender, and pointed, their superior margins slightly convex and having a general direction at right angles to the axis, their inferior margins more extensively curved, the inner or basal portion being sharply inclined to the axis, whilst the outer half is nearly horizontal. Each cellule, therefore, is somewhat curved as a whole, and is of a triangular shape, the base resting upon the common canal, and the cell-aperture being at the apex. The cellules are from 20 to 24 in the space of an inch, their general inclination being slightly upwards, or nearly at right angles to the axis. Sometimes the cellules are curved to a greater extent, and the cell-mouth points partially downwards; but this is a distinction of trivial value, and depends probably upon the mode of preservation of the specimen.

Other examples (Pl. XX. fig. 28), whilst presenting all the characters of the above, have the stipe curved into a spiral, all the volutions of which lie in the same plane, thus coming to present the form described by Geinitz under the name of G. *spiralis* (*loc. cit.*) In these inrolled specimens it is seen that G. *Sedgwickii* commences

with a slender, curved, spiral portion, provided proximally with a small radicle. The cellules here are not so long as in the adult portion of the stipe, and they are more closely arranged, attaining the number of from 30 to 40 in the space of an inch. This coiled-up proximal portion of *G. Sedgwickii* was described by Hisinger under the name of *G. convolutus*, and it also corresponds to *G. proteus* of Barrande and *G. millipeda* of M'Coy. All these pseudo-species, however, are partially referable to the base, not of the ordinary form of *G. Sedgwickii*, but of the variety *triangulatus*, Harkn., the proximal extremities of the two forms often very closely resembling one another.

Judging from the figures of *G. Clintonensis* of Hall, described from the Clinton formation (of Middle-Silurian age), this Graptolite is merely a form of *G. Sedgwickii*; and its occurrence so high in the Silurian series is worthy of note.

The normal form of *G. Sedgwickii*, Portl., as above described, occurs commonly in the Upper Llandeilo rocks of Dumfriesshire, and is found, though rarely, in the Coniston Flags of Westmoreland (Skelgill Beck near Ambleside, and Broughton Moor in Furness).

Var. *a*. SPINIGERUS, Nich.   Pl. XIX. fig. 32.

This variety is dubiously distinct from the ordinary form, and differs from it only in the fact that the cellules are provided with strong horizontal spines proceeding from their lower surfaces, and apparently attached to the inferior margins of the cell-mouths. The spines are ordinarily from $\frac{1}{25}$ to $\frac{1}{30}$ of an inch in length; but a line or more is not unfrequently attained. It is possible that these spines are normally present in *G. Sedgwickii*; but, as the great majority of examples (even when best preserved) do not exhibit any traces of them, I have thought it best to form a distinct variety for those specimens in which they occur. This view is strongly corroborated by the distribution of the species in the Coniston Flags. Thus in the flags of Mosedale in Long Sleddale it occurs in great plenty and of great size, whilst the spineless form is seldom, or never, found. In the flags of Skelgill Beck, however, which are exactly on the same horizon, the spine-bearing variety is, as far as I have seen, entirely wanting, and the species is represented by the normal form, and by the variety *triangulatus* of Harkness. In the flags of Broughton Moor, again, the ordinary form is by no means uncommon, but neither of the varieties has hitherto presented itself.

Var. *β*. TRIANGULATUS, Harkn.   Pl. XIX. figs. 33, 34; Pl. XX. figs. 1, 2.

Rastrites triangulatus, Harkness, Quart. Journ. Geol. Soc. vol. vii. pl. 1. figs. 3 *a–d*.

This is a very well-marked variety of *G. Sedgwickii*; but it seems on the whole to be only a variety, and not to be a distinct species. In some localities it prevails to the total exclusion of the ordinary form, and it is almost always the most abundant phase of the species. The stipe is simple, monoprionidian, and more or less

curved commencing with a small radicle and a slender curved proximal portion, which gradually becomes straight, or nearly straight, as it becomes fully developed. The axis is capillary, the common canal slender and very much narrower than in the normal form. The breadth of the fully grown portion of the stipe is one line or rather more. The cellules are long, triangular, and pointed, the base resting upon the common canal, and the cell-mouth being at the apex, from 20 to 30 in an inch, nearly at right angles to the axis, or directed slightly upwards, their upper and lower margins being subparallel and of nearly equal length; sometimes the breadth of the cellules is tolerably uniform, till close upon the cell-mouth, being about $\frac{1}{40}$ of an inch near the middle; sometimes, however, the inferior margin is considerably inclined to the axis, in which case the base of the cellule is expanded, and its form becomes more distinctly triangular; sometimes, again, the cell-mouths are deflexed; but in no case have they ever been observed to be provided with spines. The proximal cellules have mostly the same characters as those of the older portion of the stipe, except that they are smaller and are placed at a greater relative distance from one another. So much is this occasionally the case, that the proximal extremity may assume the characters of a *Rastrites*, and might, if observed as a fragment, be mistaken for such.

Most specimens average from $\frac{1}{2}$ to 1 inch in length; but some attain a very much greater length, though perfect examples can seldom be met with. Like the normal form this variety sometimes occurs rolled up into a spiral, the coils of which lie in one plane. Besides this, numerous variations of a minor and unimportant character occur; but the general features of the variety are very distinct.

Loc. Common in the Upper Llandeilo rocks of Dumfriesshire, and in the Coniston Flags of Skelgill Beck, near Ambleside, and Mosedale in Long Sleddale.

GRAPTOLITES FIMBRIATUS, Nich. Pl. XX. figs. 3–5.

Stipe simple, monoprionidian, about one line in breadth in the adult portion, and of unknown length, the base being slender and curved. The axis is capillary. The common canal is well marked, though narrow. The cellules are in contact for the inner half or third of their length, at right angles to the axis, or directed very slightly upwards, triangular, pectinated, and extremely closely arranged, being about 30 in the space of an inch; their breadth at the base is about $\frac{1}{30}$ of an inch, gradually diminishing towards the apex, which is either rounded off or somewhat acutely pointed, but which is never deflexed or provided with spines. The base is curved, the youngest portion closely resembling the proximal extremity of *G. Sedgwickii*, var. *triangulatus*; the cellules, however, very rapidly become broader and more closely set.

G. fimbriatus cannot be confounded with any Graptolite with which I am acquainted, and can be readily recognized even in small fragments. It is allied to *G. Sedgwickii*, Portl., in its ordinary form,

and belongs to the same natural subgroup; but it is sharply separated by the broad, tooth-like, close-set cellules, which have hardly any interval between them, so that the celluliferous edge of the stipe assumes a pectinated appearance.

Loc. Beautifully preserved in relief in the Coniston Flags of Skelgill Beck, near Ambleside ; also, of doubtful occurrence, in the Upper Llandeilo rocks of Polmoody Burn near Moffat.

GRAPTOLITES NILSSONI, Barr.   Pl. XX. figs. 16–21.

> *G. Nilssoni*, Barrande, Grapt. de Bohême, pl. 2. figs. 16, 17.
> *G. Nilssoni*, Geinitz, Graptolithen, pl. 2. figs. 19, 28, 31, & 32.
> *Monograpsus proteus*, Geinitz, ibid. pl. 4. figs. 9, 10, 11, 12, 15–18, & 20.
> *G. Nilssoni*, Harkness, Quart. Journ. Geol. Soc. vol. vii. pl. 1. fig. 7.
> *G. intermedius*, Carruthers, Geol. Mag. vol. v. pl. 5. fig. 18.

Stipe long, linear, monoprionidian, of an average breadth of from $\frac{1}{40}$ to $\frac{1}{25}$ of an inch. Axis capillary. Common canal extremely slender. Cellules long and triangular, with pointed denticles so arranged that the cell-mouth of each is situated exactly at the commencement of the next. Cellules from 18 to 20 in the space of an inch, very narrow, the cell-mouth being nearly rectangular to the axis. The " superior " wall of the cellule is, properly speaking, absent ; the " inferior " margin is about twice as long as the cell-mouth, or rather longer, inclined to the axis at from 20° to 30°, and usually slightly concave. The denticles are pointed, and are occasionally somewhat deflexed. The base is curved and extremely slender, the cellules appearing as little triangular protuberances on the axis, but preserving the same characters as in the fully developed portion of the stipe, being especially characterized by the short rectangular cell-mouths, the acute, sometimes deflexed, denticles, and the long, curved " inferior " cell-walls, which are inclined to the axis at an extremely low angle.

Var. *α.* MAJOR, Nich.   Pl. XX. figs. 20, 21.

Stipe attaining a breadth in the fully developed portion of about $\frac{1}{25}$ of an inch. Common canal comparatively well marked. Cellules 20 to 25 in the space of an inch, triangular, the cell-mouths forming a more or less acute angle with the axis, though never departing far from the perpendicular ; the inferior cell-wall about twice the length of the aperture, inclined to the axis at about 30°. The denticles acutely angular and sometimes slightly deflexed.

Var. *β.* MINOR, Nich.   Pl. XX. figs. 16, 17.

Stipe extremely narrow, being nothing more than a mere line, upon which the cell-mouths appear as little varicose knots or ampullations. Cellules long, narrow, and remote, from 18 to 20 in the space of an inch, so arranged that the cell-mouth of each is exactly at the base of the next. Cell-apertures nearly rectangular to the axis,

short, their points sometimes slightly turned down. The inferior cell-walls inclined to the axis at from 5° to 10°, and from four to to five times as long as the cell-mouths.

Like *G. Sedgwickii*, Portl., *G. Nilssoni* appears under such various forms and aspects that it is extremely difficult to draw exact limits for the species. Taken as a whole the characters of the species are sufficiently distinctive; but numerous specimens present themselves which approach closely to *G. tenuis*, Portl., to the young form of *G. sagittarius*, Linn., and to certain narrow examples of *G. Sedgwickii*, Portl., whilst all the different varieties are connected together by a series of transition forms. Three forms, at any rate, differing from one another in size and in some smaller peculiarities, seem to be sufficiently distinct to be considered genuine varieties. Of these, I have taken the one which is intermediate in size to represent the typical form of the species, the two extremes appearing to be truly varieties, and to possess characters really peculiar and not depending simply upon age or mode of preservation.

The ordinary form of *G. Nilssoni*, Barr., is characterized by the separation of the cellules, which do not overlap one another, by the short, rectangular, or nearly rectangular, cell-mouths, and by the long and slightly curved "inferior" cell-walls, which give the entire cellule a triangular shape. In *G. tenuis*, Portl., on the other hand, the cell-mouth, though also short and rectangular, transgresses upon the body of the stipe, running across the base of the cellule immediately above, whilst the inferior cell-wall is either straight or is somewhat convex. The larger variety of *G. Nilssoni* agrees with the normal form in most respects, differing chiefly in the greater width of the stipe, the more conspicuous common canal, and the fact that the cell-mouths are directed more upwards, so that the denticles become more acutely angular. The smaller variety is chiefly distinguished by its extreme tenuity, and the proportionate length of the "inferior" cell-wall when compared with the cell-mouth.

Loc. Coniston Flags of Skelgill Beck, near Ambleside; Upper Llandeilo rocks of Garple Linn, Duffkinnel Burn, &c. near Moffat.

GRAPTOLITES TENUIS, Portl.   Pl. XX. fig. 31.

    G. tenuis, Portlock, Geol. Rep. p. 319, pl 19. fig. 7.

Stipe slender, of unknown length, neither extremity having been hitherto detected, and having a breadth of from $\frac{1}{40}$ to $\frac{1}{30}$ of an inch. The cellules are from 20 to 24 in an inch, overlapping one another to an extremely limited extent, very narrow, and inclined to the axis at the very small angle of from 5° to 10°. The cell-mouths are extremely short, at right angles to the axis, and running partially across the stipe, so as to cut across the base of the cellule immediately above. The "inferior" cell-walls are straight or slightly convex, from three to four times as long as the cell-mouth, and almost parallel to the axis.

It is very questionable whether this can be maintained as a distinct species. No doubt some of the forms of *G. Nilssoni*, Barr.,

approach very closely to, if they do not agree exactly with, the description of *G. tenuis* by Portlock ; but an examination of a large series of specimens shows that these should really be referred to *G. Nilssoni*, into the typical form of which they pass by insensible gradations. The above characters are founded on specimens both from the Coniston Flags and from the Upper Llandeilo rocks of Dumfriesshire, which, if not fragmentary, are certainly distinct, though I am not in a position to assert that they agree exactly with the characters of *G. tenuis*, Portl. The *G. tenuis* figured by M'Coy (Pal. Foss. pl. 1 B. figs. 4, 5) appears to be in reality the young form of *G. sagittarius*, Linn.

Loc. Duffkinnel Burn near Wamphray, and Dobbs Linn near Moffat.

GRAPTOLITES DISCRETUS, Nich.   Pl. XX. figs. 12–15.

Stipe long, linear, and slender, commencing by a long, narrow, and gently curved base ; length unknown ; breadth from $\frac{1}{30}$ to $\frac{1}{24}$ of an inch in the fully developed portion of the stipe. Axis exceedingly fine, and sometimes prolonged beyond the distal extremity of the stipe. Common canal of great breadth, occupying about two-thirds of the entire width of the stipe. Cellules very remote, from 12 to 16 in the space of an inch, each resting directly upon the mouth of the one immediately below. Cell-mouths short, forming an oblique aperture running for a short distance across the body of the stipe, the inferior lip being prolonged into a long flexible, submucronate extension, which is usually directed upwards. The "superior" cell-wall is apparently wanting, the "inferior" margin being nearly parallel with the axis, straight or slightly convex, and from twice to three times as long as the cell-mouths.

The long, submucronate extremities of the cellules are often furnished with little ovoid, or triangular, vesicular bodies depending from their apices (Pl. XX. fig. 15).

This remarkable Graptolite differs to a marked extent from all other described forms, being distinguished by the very remote and distant cellules, almost parallel with the axis, by the great comparative width of the common canal, and by the extended, submucronate denticles. These peculiarities deprive it of even a distant resemblance to any species with which I am acquainted. The little triangular or bell-shaped vesicles, which depend from the apices of many of the cellules, are so constant in their occurrence and position, that they cannot possibly be regarded as accidental. They may possibly be reproductive, and may correspond to the "ovarian capsules" of the *Sertularidæ* ; but I have no data whereby to decide this point positively.

Loc. Coniston Flags of Mosedale in Long Sleddale, abundant and well preserved.

GRAPTOLITES BOHEMICUS, Barr.   Pl. XX. figs. 22–24.

G. Bohemicus, Barrande, Grapt. de Bohême, pl. 1. figs. 15–18.

Stipe simple, monoprionidian, of unknown length, and attaining

a breadth of nearly one line in the fully developed portion. Axis slender. Common canal narrow. Cellules from $\frac{1}{10}$ to $\frac{1}{8}$ of an inch in length, inclined to the axis at an angle of from 25° to 30°, narrow, in contact for about two-thirds of their entire length; from 20 to 25 in the space of an inch; the cell-mouths making more than a right angle with the general direction of the cellules, and forming, therefore, a very obtuse angle with the axis. Base slender and curved, somewhat resembling that of *G. sagittarius*, Linn.

This very distinct species is readily recognized by the obliquity of the long and narrow cellules, and by the open angle which the cell-mouth makes with the cell-walls. The specimens which I have discovered from the base of the Coniston Flags are exquisitely preserved in relief, and are the first examples of the species which have hitherto been found in Great Britain.

Loc. Coniston Flags of Skelgill, near Ambleside.

GRAPTOLITES PRIODON, Bronn. Pl. XX. figs. 6–8.

   G. priodon, Barrande, Grapt. de Bohême, pl. 1. figs. 1–14.
   G. priodon, Geinitz, Graptolithen, pl. 3. figs. 20–27, 29–32, 34.
   G. Ludensis, Murch. Sil. Syst. pl. 26. figs. 1, 1 *a*.

Stipe simple, monoprionidian, commencing proximally in a slender, straight or curved base, and then proceeding in a straight or slightly curved line. Axis cylindrical. Common canal well marked. Cellules in contact near the base for the inner half or thereabouts, and then gradually diverging from one another owing to the diminution of their calibre, forming an angle of about 45° with the axis, cylindrical, tapering gradually from base to apex, and varying from 22 in the adult to 30 in the younger specimens in the space of an inch. The most characteristic point, however, about the cellules is the peculiar double curve which they describe, the inner third being rectangular to the axis, the middle third bent upwards, and the outer third again curved downwards, so that the cell-mouth finally comes to look more or less completely downwards or outwards.

G. priodon, though often confounded with *G. colonus*, Barr., is readily distinguished from any other species known to me. *G. colonus* is easily separated by the shape of the frond and by the facts that the cellules are in contact throughout almost their entire length, that they do not taper gradually from base to apex, and that they want the peculiar double curvature so characteristic of the cellules of *G. priodon*.

G. priodon is not only found in the Coniston Grits and the higher beds of the Coniston Flags, but occurs likewise in the mudstones at the base of the latter, serving, therefore, to show the indivisibility of the entire series.

Loc. Coniston Flags of Broughton Moor and Skelgill Beck; Coniston Grits of Hebblethwaite Gill, near Sedbergh.

GRAPTOLITES COLONUS, Barrande. Pl. XX. figs. 9–11.

There occur in the Ludlow rocks in the neighbourhood of Ludlow,

and also in some parts of the Coniston Flags, certain small Graptolites which are decidedly distinct from *G. priodon*, and which, though they differ somewhat from the typical form of *G. colonus*, Barr., nevertheless appear to be really inseparable from it, and to be identical with one of the forms figured by Barrande (*loc. cit.* pl. 2. fig. 5).

Stipe simple, monoprionidian, from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch in length, attaining a breadth of about one line in the fully developed portion, and tapering gradually towards the base. The base is straight, and not curved, and is simply pointed, there being no proximal extension of the solid axis. The back of the stipe is often somewhat convex. The axis is capillary, and is prolonged for a short distance beyond the distal-extremity of the stipe. The cellules are from 30 to 35 in the space of an inch, inclined to the axis at about 45°, straight, free for about one-third of their entire length ; the cell-mouths are curved, nearly at right angles to the direction of the cellules, the proximal lip of the aperture being prolonged into a submucronate extension, without, however, any true spines.

The specimens from the Coniston Flags occur chiefly in the " sheer-bate" beds at the top of the series. They are too imperfectly preserved to admit of accurate determination, but they agree with the specimens of *G. colonus*, Barr., from the Ludlow rocks in the following points :—1st, in the general form of the stipe, which is from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in length, is slightly convex along the back, and tapers gradually towards the base without curving up ; 2ndly, in the prolongation of the solid axis beyond the distal end of the stipe ; and, 3rdly, in the existence of submucronate denticles.

Loc. Coniston Flags of Skelgill Beck (grey grits above the mudstones), Horton in Ribblesdale, Broughton Moor, and Ash Gill (cleaved flags), Torver Beck near Torver (" sheer-bate " flags); Coniston Grits of Casterton Low Fell, near Kirkby Lonsdale. Abundant in the Lower Ludlow rocks of Bow Bridge, near Ludlow.

GRAPTOLITES SAGITTARIUS, Linn.   Pl. XX. figs. 25–27.

> *Prionotus sagittarius*, Hisinger, Leth. Suec. Supp. p. 114, t. 35. fig. 6.
> *G. Barrandii*, Scharenberg, Ueber Grapt. t. 1. figs. 5–7.
> *G. virgulatus*, ibid. *loc. cit.* figs. 8–11.
> *G. nuntius*, Barrande, Grapt. de Bohême, pl. 2. fig. 6.
> *G. incisus*, Harkness, Quart. Journ. Geol. Soc. vol. vii. pl. 1. fig. 8.
> *G. Hisingeri*, Carruthers, Geol. Mag. vol. v. p. 126.

Stipe of unknown length, and varying in breadth from $\frac{1}{25}$ to $\frac{1}{10}$ of an inch, commencing with a long and slender radicle, prolonged into an extremely slender, usually more or less curved, celluliferous stipe, which gradually widens out and becomes straight. The delicate basal portion of the stipe may sometimes be as much as $1\frac{1}{2}$ inch in length before the cellules become fully developed and assume their normal characters. Not only is this

basal portion extremely narrow, but the cellules differ entirely from those of the adult stipe, being, in fact, undistinguishable in all their characters from those of the smaller forms of *G. Nilssoni*, Barr. The solid axis is slender and cylindrical, and in young specimens is often seen to be prolonged beyond the distal extremity of the stipe. The common canal, except in very young individuals, is sufficiently well marked. The cellules are inclined to the axis at about 45°, averaging about 25 in the space of an inch, but varying in number from 20 to 30. The cell-mouths are at right angles to the axis, each encroaching slightly upon the cellule immediately above; the denticles are angular, and rarely furnished with minute spines. The cellules overlap one another for from one-third to one-half of their entire length, the free portion being often somewhat the widest, and having a dilated and sacculate appearance.

G. sagittarius, Linn., is apparently exclusively confined to the Lower Silurian rocks, in Britain certainly, and probably abroad as well. It is of very doubtful occurrence in either the Skiddaw Slates or the Lower Llandeilo rocks proper, but it is a highly characteristic and abundant fossil in both the Upper Llandeilo and the Caradoc groups. It is found in tolerable plenty in the Coniston Flags, and it appears to have survived into the Coniston Grits.

Loc. Coniston Flags of Mosedale in Long Sleddale and Skelgill Beck, near Ambleside; Coniston Grits of Helmside, near Dent (?).

GRAPTOLITES TURRICULATUS, Barrande.   Pl. XX. figs. 29, 30.

Stipe simple, monoprionidian, and coiled up into a conical spire which does not lie in one plane, but is "trochoid" or inequilateral in form. The base commences by an obtusely pointed radicle. The solid axis is well marked, and the common canal is, comparatively speaking, of considerable breadth. The cellules are about 45 in the space of an inch, triangular, pointed, and curved, their apices being somewhat reflexed and provided with small spines.

G. turriculatus, Barr. (perhaps the most elegant species of the entire genus), has not hitherto been detected out of Bohemia; but I have been fortunate enough to discover several specimens of it in the Coniston Flags. The form is one that cannot possibly be confounded with any other yet described, being immediately distinguished by the helicine curvature of the stipe, and by the close-set, curved, mucronate denticles.

Loc. Coniston flags of Mosedale in Long Sleddale.

Correlation of the Coniston Flags with foreign deposits.

By way of conclusion to this paper it may be as well to make a few remarks on the correlation of the Coniston Flags with the Graptolitiferous rocks of Bohemia and with the Utica Slates of America.

According to Barrande, there are in Bohemia two zones in which Graptolites occur—one (étage D) at the summit of the Lower Silurian, and the other (étage E) at the base of the Upper Silurian division, the two being separated by a series of trappean rocks. In the former or lower zone occur *G. priodon*, Bronn, *G. Bohemicus*,
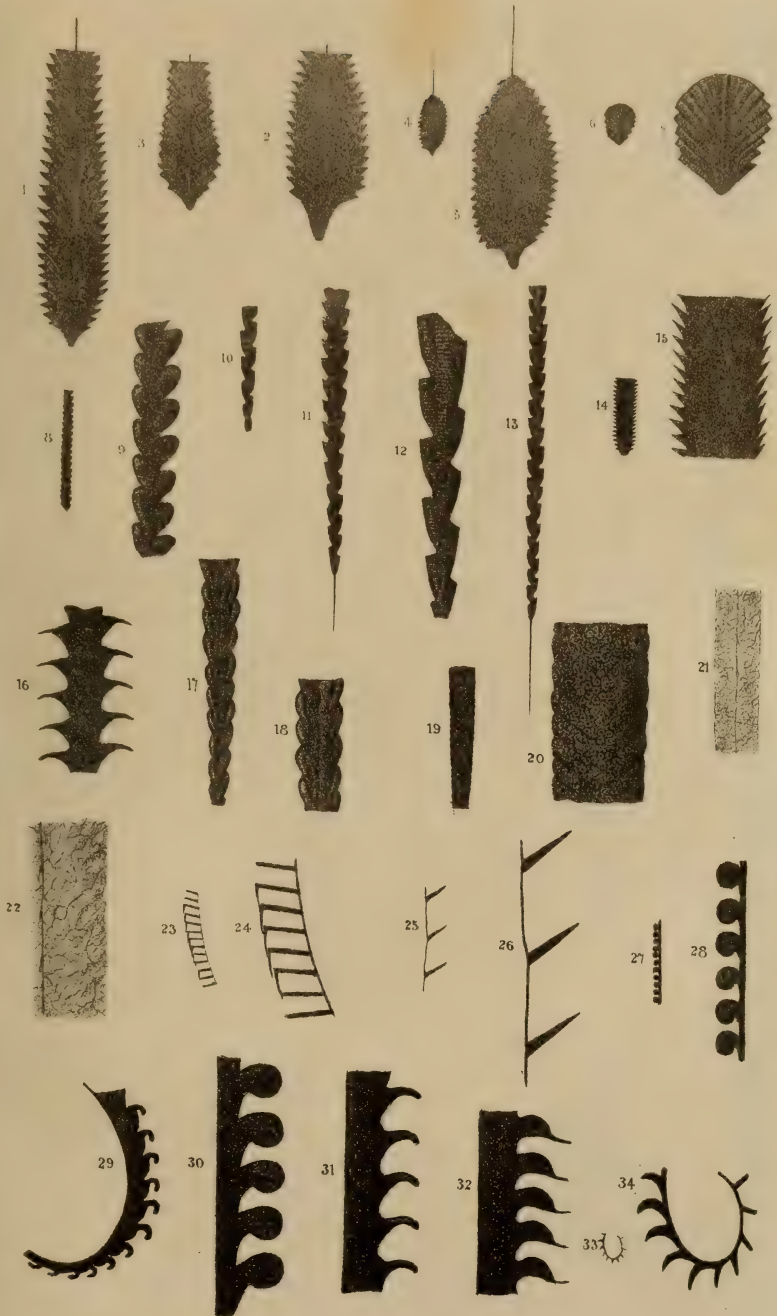
A.T Hollick del et lith.

M & N Hanhart imp

GRAPTOLITES FROM THE CONISTON FLAGS.
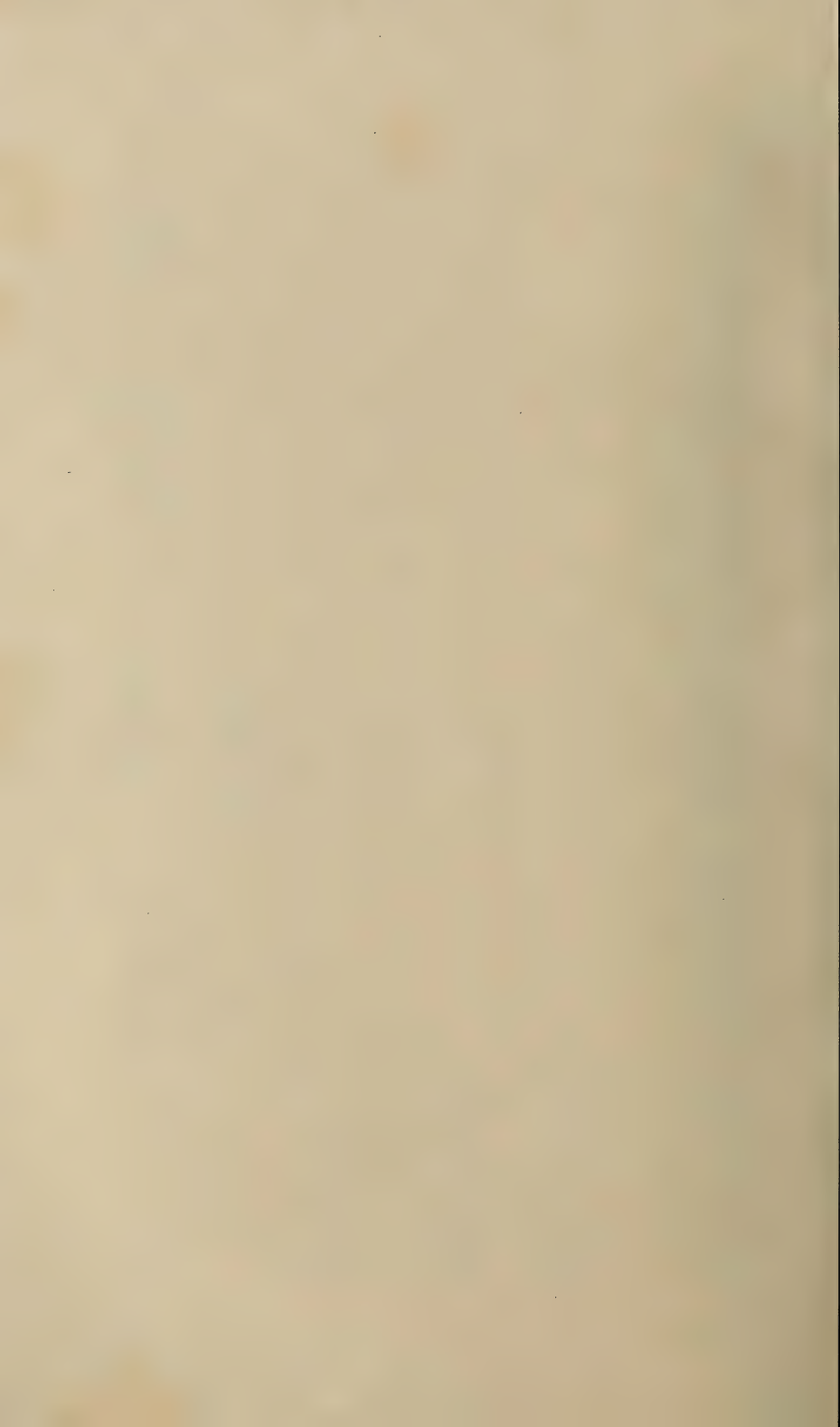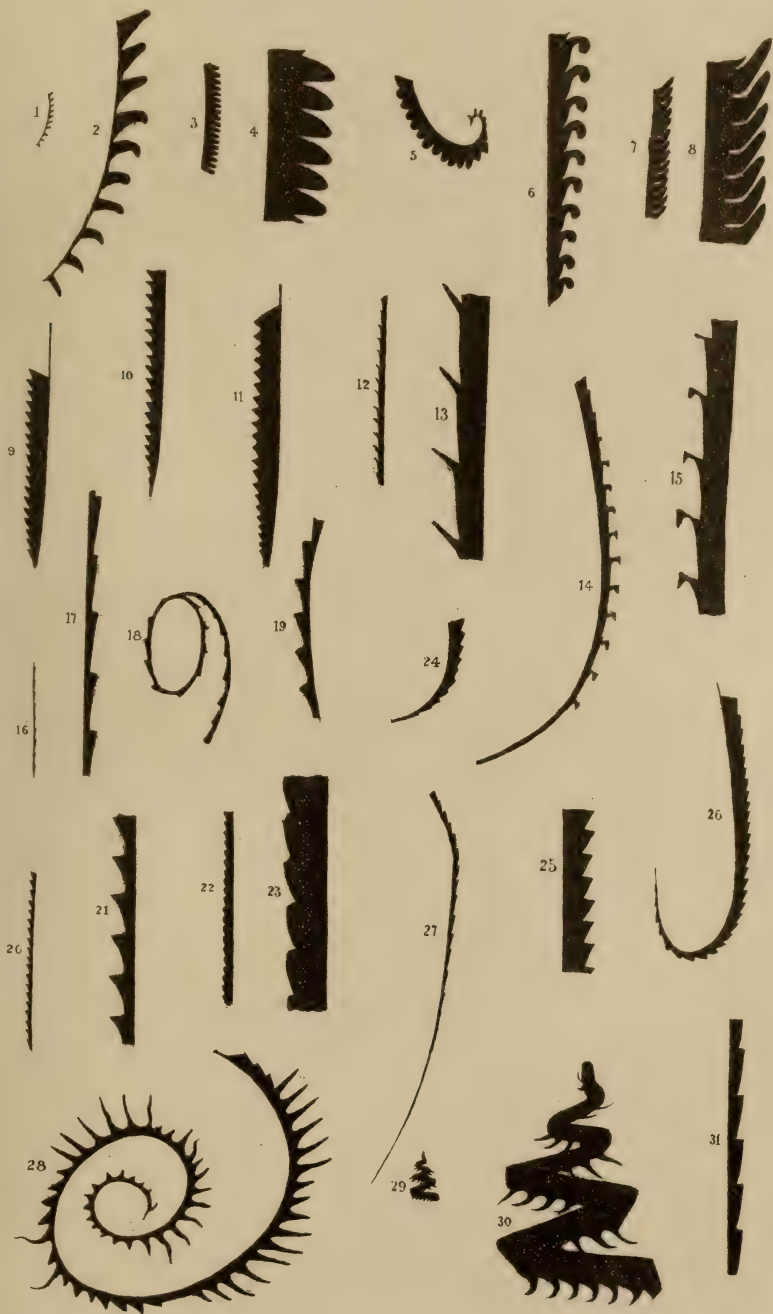
A T Hollick del et lith

M & N Hanhart imp

GRAPTOLITES FROM THE CONISTON FLAGS.
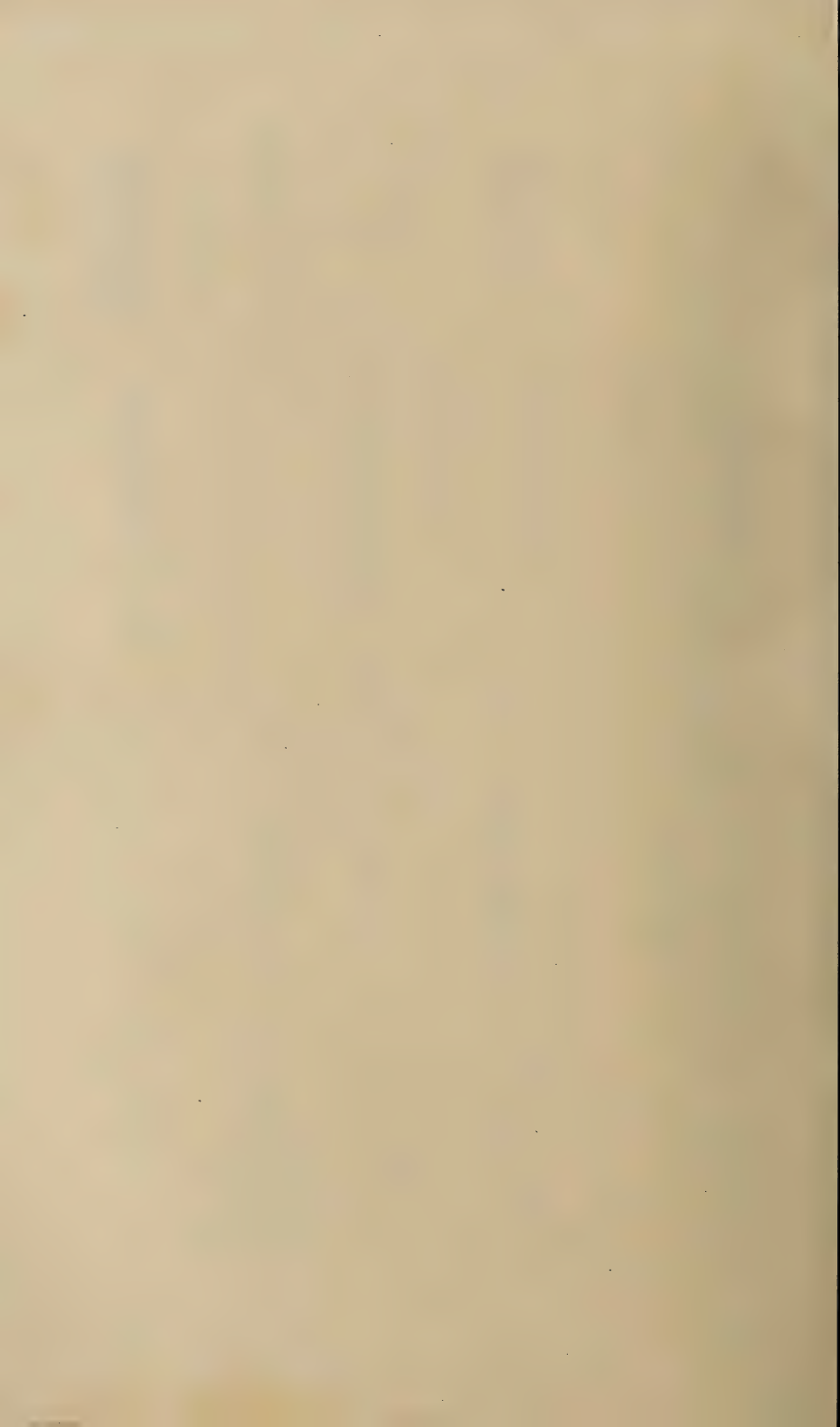
Barr., *G. Rœmeri*, Barr., and *G. colonus*, Barr. In the upper zone, besides all the above, there occur *G. lobiferus*, M'Coy, *G. Nilssoni*, Barr., *G. Sedgwickii*, Portl. (= *G. spiralis*, Gein., and *G. proteus*, Barr.), *G. turriculatus*, Barr., *Diplograpsus palmeus*, Barr., *Rastrites peregrinus*, Barr., *R. Linnæi*, Barr., *Retiolites Geinitzianus*, Barr., and other species. From the above lists, even were there nothing else to go by, we should be certainly inclined to believe that M. Barrande was in error in separating the two Graptolitiferous zones, and in placing the higher one (étage E) at the base of the Upper Silurian series. The species *G. lobiferus*, *G. Nilssoni*, and *G. Sedgwickii*, with *Diplograpsus palmeus* and the two species of *Rastrites*, are all found in the Upper Llandeilo rocks of Dumfriesshire; whilst the genera *Diplograpsus* and *Rastrites* have never been proved, as yet, to transcend the limits of Lower Silurian rocks. These facts are of themselves sufficient to render it highly probable that étage E is truly of Lower Silurian age; and an examination of the Graptolites of the Coniston Flags makes this conclusion almost inevitable. In the Coniston Flags, namely (and this of itself is a singular fact), there occur all the Bohemian species above mentioned as characteristic of the upper zone, or étage E, of Barrande. Some of these, too, are very peculiar and local in their distribution, such as *G. Bohemicus*, Barr., *G. turriculatus*, Barr., and *Retiolites Geinitzianus*, Barr. Not only is this so, but these same species are found in the Flags to be coexistent with several familiar Upper-Llandeilo and Caradoc species, such as *Climacograpsus teretiusculus*, His., *Diplograpsus pristis*, His., *D. angustifolius*, Hall, and *D. tamariscus*, Nich. In fact, out of the twenty-four species of Graptolites from the Coniston Flags, if we except five new species as useless for purposes of classification, we find twelve out of the remaining nineteen, or more than three-fifths of the whole, to be common to the Flags and to Barrande's étage E. From these facts we are justified in coming to the conclusion that the main Graptolitiferous zone of Bohemia (étage E) is homotaxeous, if not strictly cotemporaneous, with the Coniston Flags of Cumberland and Westmoreland, and that both are truly of Lower-Silurian age.

A decided relation, though not nearly so marked a one, can also be shown to exist between the Coniston Flags and the Hudson-River group and Utica Slates of America. Five species, at any rate, are common to the two formations, viz. *Climacograpsus teretiusculus*, *Graptolites sagittarius*, *Diplograpsus pristis*, *D. angustifolius*, and *D. putillus*, of which the last two were first described from American specimens. As the Hudson-River group is of Caradoc age, an additional corroboration is thus furnished to the view that the Coniston Flags should be looked upon as a portion of the Caradoc or Bala series.

EXPLANATION OF PLATES XIX. & XX.

PLATE XIX.

Fig. 1. *Diplograpsus palmeus*, Barr., ordinary form, natural size. From the Upper Llandeilo shales of Dumfriesshire.

2. Specimen of the same, enlarged. From the Coniston Flags of Skelgill.
3. Another example of the same, possessing a peculiar fusiform shape, and showing the lines of growth running parallel to the cell-mouths; enlarged. From the Upper Llandeilo rocks of Dumfriesshire.
4. *D. folium*, His. (=the young form of *D. palmeus*?), natural size. From the Coniston Flags of Skelgill.
5. The same, enlarged.
6. Small rounded example of *D. folium* (= *D. palmeus*?), natural size. From the same locality as the last.
7. The same, enlarged, to show the lines of growth.
8. *D. angustifolius*, Hall, natural size. From the Coniston Flags of Skelgill Beck.
9. The same, enlarged. This specimen is shown obliquely, so that the cellules appear to be more distinctly alternate than they really are.
10. Base of *D. tamariscus*, Nich., natural size. Upper Llandeilo, Dumfriesshire.
11. Specimen of *D. tamariscus*, showing a basal extension of the axis; enlarged. Upper Llandeilo, Dumfriesshire.
12. Fragment of *D. tamariscus*, enlarged. From the Coniston Flags, preserved in relief, and showing transverse striæ.
13. Another specimen of the same, almost perfect, enlarged. From the Upper Llandeilo rocks of Dumfriesshire.
14. Fragment of *D. confertus*, Nich., natural size. From the Coniston Flags of Skelgill.
15. The same, enlarged.
16. Fragment of *D. mucronatus*, Hall, enlarged; introduced for comparison.
17. Specimen of *D. putillus*, Hall, slightly enlarged. From the Coniston Flags of Skelgill.
18. Portion of the same, enlarged still further.
19. Fragment of *Retiolites Geinitzianus*, Barr., natural size. From the Coniston Flags of Broughton Moor.
20. The same, enlarged to show the punctation of the test.
21. Fragment of *R. perlatus*, Nich., natural size. From the Coniston Flags of Mosedale.
22. Portion of the same, enlarged, to show the peculiar reticulation of the test.
23. Fragment of *Rastrites peregrinus*, Barr., natural size. From the Coniston Flags of Skelgill.
24. The same, enlarged. The appearance in this figure of appendages attached to the apices of the cellules at right angles is simply produced by fragments of another contiguous specimen.
25. Fragment of *R. Linnæi*, Barr., natural size. From the Coniston Flags of Mosedale.
26. The same, enlarged.
27. Fragment of *Graptolites lobiferus*, M'Coy (var. *exiguus*, Nich.), natural size. From the Coniston Flags of Skelgill.
28. The same, enlarged.
29. Fragment of *G. lobiferus*, near the base, enlarged. From the Upper Llandeilo rocks of Dumfriesshire.
30. Fragment of *G. lobiferus*, M'Coy, showing the cavities occupied by the polypites; enlarged. From the Upper Llandeilo rocks of Dumfriesshire.
31. Fragment of the ordinary form of *G. Sedgwickii*, Portl., enlarged. From the Coniston Flags of Broughton Moor. In this specimen the common canal is relatively wider and the cellules smaller than is the case in ordinary examples.
32. Fragment of *G. Sedgwickii*, Portl. (var. *spinigerus*, Nich.), enlarged. From the Coniston Flags of Mosedale.
33. Fragment of *G. Sedgwickii*, Portl. (var. *triangulatus*, Harkn.), near the base; natural size. From the Coniston Flags of Skelgill.
34. The same, enlarged.

Plate XX.

Fig. 1. Fragment of *Graptolites Sedgwickii*, Portl. (var. *triangulatus*, Harkn.), natural size. From the Coniston Flags of Skelgill. An unfortunately small example has been figured here, but much larger ones are found in the flags.

2. The same, enlarged.

3. Fragment of *G. fimbriatus*, Nich., natural size. From the Coniston Flags of Skelgill. This is a mere fragment, but its position should be reversed.

4. The same, enlarged.

5. Base of *G. fimbriatus*, enlarged.

6. Fragment of *G. priodon*, Bronn, enlarged. From the Coniston Flags of Broughton Moor.

7. Another specimen of *G. priodon*, exhibiting a somewhat different view.

8. The same, enlarged.

9. Imperfectly preserved specimen of *G. colonus*, Barr., natural size. From the Coniston Flags of Horton in Ribblesdale.

10. Fragment of *G. colonus*. From the Coniston Grits of Helmside, near Dent.

11. Nearly perfect example of *G. colonus*, Barr., enlarged. From the Lower Ludlow rocks of Bow Bridge, near Ludlow.

12. Fragment of *Graptolites discretus*, Nich., natural size. From the Coniston Flags of Mosedale.

13. The same, enlarged.

14. Another specimen of *G. discretus*, showing the tapering curved base, natural size. Many of the cellules in this specimen have vesicles attached to their apices,

15. Fragment of another specimen of the same, showing vesicular bodies, apparently attached to the apices of the cellules; enlarged.

16. Fragment of *G. Nilssoni*, Barr. (var. *minor*, Nich.), natural size. From the Upper Llandeilo rocks of Dumfriesshire.

17. The same, enlarged.

18. Fragment of *G. Nilssoni*, Barr., of the ordinary form, natural size. From the Coniston Flags of Skelgill.

19. The same, enlarged.

20. Fragment of *G. Nilssoni*, Barr. (var. *major*, Nich.), natural size. From the Upper Llandeilo rocks of Dumfriesshire. In most examples of this variety the cell-mouths form a more acute angle with the axis.

21. Portion of the same, enlarged.

22. Fragment of *G. Bohemicus*, Barr., natural size. From the Coniston Flags of Skelgill.

23. The same, enlarged.

24. Base of the same, enlarged.

25. Fragment of *G. sagittarius*, Linn., enlarged. From the Coniston Flags of Mosedale.

26. Complete specimen of *G. sagittarius*, Linn., in its young condition, showing the distal prolongation of the axis, the slender curved base, the resemblance of the youngest cellules to those of *G. Nilssoni*, Barr., and the delicate radicle; slightly enlarged. From the Upper Llandeilo rocks of Garple Linn, near Beattock.

27. Base of another specimen of *G. sagittarius*, still more extensively developed; natural size. From the Upper Llandeilo rocks of Frenchland Burn, near Moffat.

28. Specimen of *G. Sedgwickii*, Portl., coiled into a spiral the volutions of which lie in one plane (= *G. spiralis*, Gein.); enlarged. From the Upper Llandeilo rocks of Dumfriesshire.

29. Small specimen of *G. turriculatus*, Barr., natural size. From the Coniston Flags of Mosedale.

30. The same, enlarged.

31. Fragment of *G. tenuis*, Portl. (?), enlarged. From the Upper Llandeilo rocks of Dumfriesshire.

16. *On the* "WATERSTONE BEDS" *of the* KEUPER, *and on* PSEUDO-MORPHOUS CRYSTALS *of* CHLORIDE *of* SODIUM.   By G. W. ORMEROD, Esq., M.A., F.G.S.

[The publication of this paper is unavoidably deferred.]

(Abstract.)

Between Salcomb Mouth and the River Sid, and between Bud-leigh Salterton and Littleham Bay, several beds of ripple-marked "Waterstone" occur, and also pseudomorphous crystals of chloride of sodium.   One small fragment of Waterstone exhibits apparently traces of reptilian remains.   In conclusion, the author draws atten-tion to the fact that pseudomorphs occur over the greater part of the Triassic area in England.

17. *On the* DISCOVERY *of the* REMAINS *of* CEPHALASPIDIAN FISHES *in* DEVONSHIRE *and* CORNWALL; *and on the* IDENTITY *of* Stegano-dictyum, M'COY, *with* GENERA *of those* FISHES.   By E. RAY LAN-KESTER, Esq., Ch. Ch., Oxford.

[Communicated by Henry Woodward, Esq., F.G.S.]

I BEG to draw attention to a most important and interesting dis-covery which has been recently made in the cabinet of my late friend Lieut. Wyatt-Edgell.

Mr. Salter, in looking through the collection, came upon a spe-cimen of the supposed Sponge *Steganodictyum Cornubicum*, from the Lower-Devonian slates of Mudstone Bay, which, with his usual sagacity, that naturalist at once observed bore strong resemblance in shape and in structure to the shield of Pteraspids; and on com-parison with other specimens and M'Coy's figures, he came to the remarkable conclusion that M'Coy's supposed Sponge is actually the cephalic plate of a Pteraspidian fish.   Having, by the kind-ness of my friend Mr. Henry Woodward, had an opportunity of examining Mr. Wyatt-Edgell's specimens, and comparing them with Professor M'Coy's figures, I can most fully endorse Mr. Salter's determination—the nacreous, cancellated, and striated layers de-scribed by Professor Huxley, and so eminently characteristic of the Heterostracous Cephalaspidæ, by their presence leaving no room for doubt.   It was obviously desirable that Mr. Wyatt-Edgell's Pte-raspid should be compared with the only other species known from beds of the same age, viz. the *Scaphaspis Dunensis*, originally de-scribed by Roemer as a Cephalopod.   This Mr. Woodward and I were fortunately able to do, since the reputed single specimen of Roemer's fish-plate from Daun, in the Eifel, forms part of our National collection.   Though the specimen from Devonshire is by no means as satisfactory an example as we may hope hereafter to obtain, it is sufficiently well preserved to indicate a head-shield larger than any from our Cornstones, and of that simple ovoid form which characterizes the genus *Scaphaspis*, and of which *S. Ludensis, S. trun-*

catus, S. Knerii, S. Dunensis, S. Lloydii, and *S. rectus* are the species. It evidently belongs to that section of the genus which contains *S. Dunensis, S. Lloydii*, and *S. rectus,* not exhibiting the longitudinal median ridge, nor marked by the spinous posterior terminations which characterize the species *S. Ludensis, S. truncatus,* and *S. Knerii,* species which belong to the Silurian rather than the Devonian epoch. The substance of the shield is thinner in the Devon and Cornish specimens, in proportion to the large size of the shield, than in other Heterostracous Cephalaspids; the surface-ridges are exceedingly fine, about 150 to the inch, indicating in this respect, again, affinity with *S. Lloydii* rather than with the older species, which have coarse ridges. Specimens in the Museum of Practical Geology indicate a shield of double the size of Mr. Wyatt-Edgell's—that is, more than a foot in length.

On careful comparison with Roemer's *S. Dunensis,* I see no reason for separating the two specifically. Mr. Wyatt-Edgell's specimen agrees completely with that species in size and in contour, also in the size of the cavities of the middle layer of the shield-substance, and in the size of the surface-ridges, though one might be very much misled on this matter by Roemer's figure in the ' Palæontographica,' vol. iv. tab. xiii. Since M'Coy's specific name *Cornubicum* bears date 1851 (Ann. & Mag. Nat. Hist. 2nd ser. vol. viii.), whilst Roemer's name *Dunensis* is as late as 1855, the latter will have to give place to the former, and the fish headplates from the Lower Devonian rocks of the Eifel and of Devonshire and Cornwall must be known as *Scaphaspis Cornubicus.*

From an examination of Prof. M'Coy's figures and of a specimen in the Museum of Practical Geology I have little doubt that the *Steganodictyum Carteri,* which has a tuberculate ornamentation, indicates a fish allied to the genus *Cephalaspis*—that is to say, belonging to my section Osteostraci of Cephalaspidian Fishes. (See Monogr. of Old Red Fishes, Palæontographical Society, 1868.) It is to be hoped that specimens showing the form of the head-shield may soon be discovered[*].

I will not venture to remark upon the important bearing which the discovery of these fish-remains must have on the recently disputed age of the strata in which they occur. Mr. Etheridge and Dr. Holl have already hastened to apply the evidence which is thus furnished; and to their papers I must refer.

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[*] Mr. Pengelly, I am informed, has long had specimens of *Sc. Cornubicus,* which he, at the suggestion of the Rev. W. S. Symonds, submitted to Professor Huxley, who at once pronounced them to be the remains of Pteraspidian fish (previously to Mr. Salter's determination). Mr. Pengelly will no doubt soon obtain better specimens of both the Devonshire fishes. The merit of first recognizing the fish-nature of these remains belongs to Mr. Peach, who more than twenty years since wrote of them as such.

18. *On the* GEOLOGICAL PECULIARITIES *of that part of* CENTRAL GERMANY *known as the* SAXON SWITZERLAND. By the late JAMES CLARK, Esq., Directing Engineer of the Royal Arsenal, Naples; Captain in the Italian Marine; Chevalier of the Neapolitan Order of Francesco Primo, and of St. Stanislaus of Russia.

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.]

[Abridged.]

THE south-eastern part of Saxony, traversed by the Elbe, and formerly called the Meissner-Hochland, consists of a plateau of Quadersandstein cut into, especially in the northern portion, by ravines and deep and rugged valleys, and bearing numerous rocky precipitous hills, mostly of basalt, altogether forming the highly picturesque and peculiar country known as the Saxon Switzerland. At Pirna, on the north-west, the sandstone district is 450 feet above the sea and 120 feet above the river-valley; and it gradually increases in elevation towards the south-east until it reaches 960 feet above the sea, forming an inclined and uneven plateau, irregularly rectangular in form, about twenty miles long from east to west, and fifteen miles broad from north to south, with a mean elevation of about 640 feet. The plateau is traversed from south-east to north-west by the Elbe, from Tetschen, in Bohemia, to Pillnitz. Above the general level of the plateau rise a number of isolated, picturesque, rocky eminences, which increase in height gradually from north-west to south-east, thus coinciding with the general inclination of the plateau; they are situated in somewhat straight and parallel lines, almost coincident with that part of the river's course which is south-west to north-east from Schmitka (near the Larger Winterberg) to Pirna, beyond the Bärenstein.

This sandstone region is bordered by the Lusatian granite hills to the N.N.E., along an irregular line, running through Hinter-Hermsdorf, Hohnstein, and Saxon Dittersbach, the last being about five miles north of Pirna. Its western edge abuts on the schist and gneiss of the Erzgebirge. The southern boundary, from Tyssa eastwards, consists of a line of broken and inclined cliffs falling abruptly on the basaltic region of the Bohemian Mittelgebirge. To the east the Quader stretches far into Bohemia, whilst patches also occur to the west of the plateau.

The Quader and its fossils have been fully described by the German geologists, as well as the Pläner, which, underlying the former, comes out in the Elbe Valley below Pirna. At Dresden the Quader and Pläner together were found (in an Artesian bore) to have a thickness of about 800 feet, and to repose on the Rothliegendes. At about twenty-two miles to the south-east is the Larger Winterberg, having a height of 1653 feet, exclusive of its basaltic cap; and as the Elbe at its foot is 360 feet above the sea, there is a thickness of 1293 feet for the Quader, without reckoning what may be below the river-level. This, however, is probably not much; for at Niedergrund, about four miles further up the

river, and on its left bank, the granite appears at 50 or 60 feet above the river, with the Quader lying horizontally upon it ; and as this is one of the highest points in the region, and apparently free from up-heaval, 1400 or 1500 feet may be considered the maximum thickness of the Quader, though it was probably much thicker originally.

There are some marked geological peculiarities in this Saxon Switzerland, which are briefly described in the following pages.

1. *The abrupt and significant variations of surface-altitude, without any corresponding inclination or dislocation of the strata.*—The entire region lying to the northward of a line drawn between Pirna and the Larger Winterberg is made up of strata which, except in two or three localities of but small extent, are horizontal up to the tops of the highest hills, some of which reach to 1300 feet above the surface of the Elbe. The only places, worth mentioning, where this slight deviation from the general horizontality is found are :—(1) in the bends of the river round the Lilienstein*, where the strata dip to the north-east at an angle of about 1° 11′ ; and (2) in the valley of the Kirnitsch, about five miles east of the former place, and two miles E.N.E. of the town of Schandau ; here the fall is to the S.S.E. at an angle of about 15°. This place is close to the edge of the Lusatian granite, which here reaches its furthest limit southward, the border-line of the sandstone running from this spot nearly due east as far as the confines of Bohemia on the one hand, and north-west to Saxon Dittersbach on the other, thus forming the two sides of a very obtuse angle, the blunted apex of which is separated from the main body of the granite by the Kirnitsch, a small stream, which runs through it, cutting off a strip of about a mile long and not more than 200 or 300 yards wide. The sandstone and granite rise here in close contact until they both reach the height of about 940 feet above the sea, and 520 above the valley.

This rather significant inclination of the strata extends to but a few hundred yards from the edge of the granite, and would seem to have been occasioned by pressure of that rock against the edges of the sandstone beds, crushing back, as it were, the lower strata, and causing them to lift up those above.

With these two exceptions, the strata are horizontal, or very nearly so, throughout the whole of the region to the north of the line above mentioned. In passing, however, to the south of that line we find them nearly everywhere to be slightly and pretty regularly inclined, the dip taking three general directions as follows :—

1. In the western portion, lying between the border south of Pirna and a line from Prossen on the Elbe, through the Sattel-berg, the dip is about north-east, and the angle between 1° and 2°.

2. In the portion between the last-mentioned line and one drawn from Schandau due south, the dip is about N.N.W., as may be best seen in the Biela valley between the Schneeberg and the town of Königstein, the angle varying between 1° and 2°.

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* The river runs here in directions nearly at right angles to the general line of its course between the Larger Winterberg and Pirna, crossing the line mentioned above, and entering the region of inclined strata.

3. In the eastern portion the dip is about north-west, and the angle the same as in the others.

It will thus be seen that a semicircle to the south of the line through Pirna and the Winterberg, having its centre at Schandau, and a radius equal to the distance between that town and Pirna, would enclose in a general manner the whole region of inclined strata; and the mean directions of dip above particularized appear to be pretty nearly at right angles to the general border-line in the three divisions.

It will be seen, also, that the elevation of the isolated hills and rocks above the general level of the plateau is not due to any inclination of the strata; nor can it be owing to any fracture or dislocation; for in the Elbe valley, which skirts the feet of several of these eminences, and where the strata have been laid bare either by natural causes or by quarrying, there does not exist a fault even to the extent of a few inches. This fact is well exemplified in the quarries under the Lilienstein on the right bank of the river, and also in the cliffs which form the side of the Elbe valley between the villages of Schmitka and Herrnskretschen, where it cuts across the foot of the Larger Winterberg in a curve from north-west to south-east.

The general appearance of these rocky heights would seem to indicate their having been subjected to the continued action of a sea whose relative level has not varied more than a few feet through a long succession of ages subsequent to the Cretaceous period, during which time the whole region must have been quite, or nearly quite, level; for in whatever part they may be seen rising above the surface of the plateau, and from whatever direction they may be viewed, they offer a remarkable peculiarity of form, and, so far as regards the general profile, an equally remarkable resemblance one to another.

They may be best described as irregularly prismatic blocks, of various sections and diameters, about 180 feet high, set upon truncated pyramidal bases of corresponding sections, and 285 in height, or thereabout, the whole thus reaching to an altitude of some 470 feet above the plateau at their feet, and offering outlines similar to those which some of the small islands in the Mediterranean might be expected to represent, were the surface of that sea to be rapidly lowered 285 feet.

That this peculiarity of form is a consequence of the action of the waves and currents of a sea whose level must have coincided for ages with the top of the sloping bases just mentioned, appears to be evident, —first, from the fact that these bases do not consist of mere masses of loose blocks and detritus, which would have been the case had they owed their origin to the falling away of the sides of the rocks on to dry ground, but of solid and continuous strata, corresponding in every respect with the rest of the formation, as may be seen at the foot of the Lilienstein and of the Königstein; and, secondly, from the existence of caverns in the cliffs which form the sides of these eminences, evidently hollowed by the sea, being found in different parts at nearly the same relative level as regards the pyramidal basis of the

rocks above mentioned, but at absolute altitudes corresponding with their positions on the plateau.

According to this hypothesis, this part of the earth's crust must have undergone a continuous and gradual upheaval subsequent to the deposition of the Quader, until it reached an altitude of about 1420 feet below its present mean level; and after standing at this point for a long time, another, and probably the last, upheaval commenced; and this has lifted the south-east end of the plateau about 2020 feet, and the north-west 830 feet higher than they stood during the period of quiet which preceded this last upward movement.

Section illustrating the last upheaval of the Plateau of Saxon Switzerland.
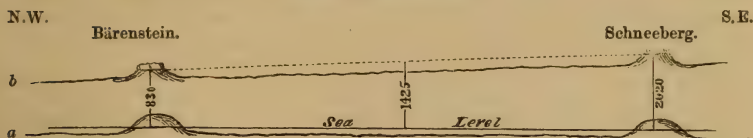
Thus in the annexed section, *a* would represent the relative levels of sea and land during the period in which the upper parts of the rocks received their present forms, and *b* the relative levels at the present day, of the north-west and south-east extremities of the plateau, the space between the two being the amount of upheaval.

All along the southern border-line, from Tyssa to beyond Tetschen, a distance of about eight geographical miles, but more especially towards its eastern end, we meet with unmistakeable evidences of a sudden break off and fall of that portion which must at some period have existed to the south of this line. The sandstone rises here some hundreds of feet above the level of the country, which borders it immediately to the south in a succession of precipitous shelves, with slopes of débris at their base. In these shelves the strata dip to the south-east, a direction directly opposite to that of the inclination of those lying to the north of the line of fracture. The angle towards the western end of the line is about 5°; a mile or two further to the east it increases to from 10° to 20°; and between Bunanberg and Tetschen we meet cliffs whose strata have a dip of from 25° to 30°, all falling in the same direction, towards the basaltic regions of Bohemia. The Schäferwand, an enormous rock on the left bank of the Elbe opposite Tetschen, is a good specimen of the whole line: this rock, through which a railway-tunnel is driven, is about 280 feet high above the valley, and stands separated from the main region of sandstone to the north by a deep ravine. The strata, which are well seen on its eastern face, dip to the south-east at an angle of from 25° to 30°.

It would thus appear that the whole of that part of the Quader formation which at the time of its deposition reached beyond this point to the southward, must have been separated from the northern portion by an enormous fracture of the earth's crust, subsequently

filled up by the Tertiary deposits of the Mittelgebirge region ; or the northern portion may have been lifted bodily and slowly away from that lying to the south of this line, the latter remaining at a comparatively great depth, and becoming covered by the more recent formations.   Be it as it may, no member of the Quader group comes to the surface again until we reach the neighbourhood of Leitmeritz, a distance of between thirty and forty miles further south.

2. *Remarkable regularity of the lines of parting, especially as regards their horizontal direction.*—Wherever the rock is exposed to view, either as forming the precipitous sides of the countless and beautiful ravines which intersect the plateau in every part, and those of the craggy eminences which stud its surface, or in the quarries situated along the banks of the Elbe and elsewhere, it is seen to be divided by fissures running more or less vertically through all the strata, and crossing each other very nearly at a right angle, hardly ever deviating more than 15° from that angle at the point of intersection.

Where the clefts toward the top have been widened and rendered conspicuous by the action of water and weather, many of these exposed parts bear no very distant resemblance to old walls of masonry, crowned here and there by square towers and pinnacles more or less worn and disfigured by time.   Some of these tower-like blocks are quite detached from the main rock, and rise layer above layer to a height of 200 feet or more, with sides so flat and smooth, and corners so sharp and square, as almost to bear comparison with the ruder specimens of columnar basalt.   The distances between the fissures may vary from a few inches to many feet.   Those which are but a short distance apart offer sometimes a very remarkable approach to parallelism*.   Slabs of about 4 inches thick by 8 feet long

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* This peculiar disposition of the lines of parting, which causes the rock to break up into nearly rectangular blocks, has given to it its German name of " Quader," and is of great technical importance as regards the mode of quarrying, which is somewhat peculiar.   Gunpowder is very rarely used, the usual manner of operating being to undermine a long piece of the face of the cliff, called by the quarrymen the " Wand " or wall, by cutting out one of the lower strata backwards nearly as far as to the next longitudinal fissure, the length of the piece so undermined being generally determined by the distance between two convenient transverse cracks.   The whole superincumbent mass, in some cases 150 feet high by 200 feet long and from 30 to 40 feet thick, is thus left without support, save what is given by the small portion of the lower stratum left uncut towards the back, and a number, greater or less according to circumstances, of wooden props placed under its fore edge.   These are examined from time to time by the overlooker, who by trying them with a hammer becomes aware of the first indications the undermined rock may give of sinking ; the top of the cliff is also examined from time to time.   When the mass is not too large, and gives signs of falling before the process of undermining has been carried very far back, the props are cut out by the axe ; but if the piece to be brought down be very large, and, being bound at the ends, requires to be cut under to a distance much beyond the line of its centre of gravity, it gives but short warning, settling rapidly on to the props, and would give no time for the workmen to get out of the way, were they to attempt to cut these out in the usual manner ; in such cases they are pierced with auger-holes and blasted out simultaneously, when the enormous mass leans forward and comes to the ground with a crash that is often heard and felt for miles round.

and 6 feet broad occur almost as flat and equal in faces as dressed blocks.

The general direction of the two main lines of parting is about N.N.W. to S.S.E., and W.N.W. to E.S.E.   The deviations from these (which may be called regular) lines do not exceed, save in rare instances, 15° or 20° on either side, except in localities where the rock appears to have been subjected to the influence of agencies entirely unconnected with and different from those which originated the fissures or determined their directions*.

3. *The remarkable phenomena observable along the line of separation between the Quader and the Lusatian Granite, bordering it to the northward.*—The relative positions of the Quader and associated strata and of the syenite or granitic rocks along this line have been closely observed and described by several geologists of high repute, and have given rise to several hypotheses to account for the origin and movements of the several rock masses.

Weiss gave it as his opinion that the granite and syenite in a hardened state, together with the calcareous strata of Holstein, were by subterranean action forced upwards and sideways on to the sandstone.

Klipstein inclined to the theory that the granite was in its present condition and relative position before the Cretaceous period, and that the Quader was consequently deposited against, or under, the cliffs which constituted its southern border.

Gumprecht considered the granite and syenite of this region to be coeval formations with the Quader; that is to say, that the Lusatian granite is a newer formation than the syenite of the left bank of the Elbe, and that, *if it be of plutonic origin,* it broke through a long rent in the older rocks a little to the north of the Quader border, which at that period formed the south shore of the channel of drainage of the Bohemian Basin.   The newly ejected granite, running up to, and in some parts over, the sandstone, dammed up that channel and converted the country lying to the south-east into an inland sea, whose level rising over the new dam and sandstone already deposited caused new deposits of the latter.   In this manner the origin of those isolated portions of Quader found here and there outlying the main region to the west and north-west may, he thinks, be accounted for as being portions of this second deposition, on parts of the granite lying at that period below the level of the pent-up waters.

Cotta appears to have been of opinion that the Quader of the Saxon Switzerland extended originally much further to the north, covering the granite, which at that period lay at one general level—and that that portion of the latter rock which now forms the Lusatian hills and the rest of the region to the northward of the border-line, with the overlying sandstone, was uplifted at least a thousand feet, leaving the part to the south of the line unmoved.   The sandstone, thus severed from and lifted above the rest, would, in the common nature of things, be much fractured, and rendered exceedingly vulnerable

* See Gutbier's ' Geognostische Skizzen aus der Sächsischen Schweiz,' 1858.

to the attacks of subsequent denuding agents; and this may be accounted for, according to this geologist, by the non-existence, at the present day, of any remains of the Quader, which formerly overlay these granite hills.   He also attributes the presence of the Jurassic limestone at Hohnstein to the upheaval of the granite, which, bringing that small portion of this rock found there from its place of deposit beneath the sandstone, crushed and rubbed it, during its passage, into the state of conglomerate in which it is now found; while the fact of the granite overlying the newer formation here and elsewhere, he thinks, may be accounted for by the plutonic rock having been subjected to a side movement in some parts, simultaneously with the general vertical one throughout.

The author having had many opportunities of examining and studying portions of the division-line between the two rocks, formed the opinion that no one of these theories can be said to account in a satisfactory manner for all the phenomena which that line presents. The first and last, namely, those by Weiss and Cotta, do, no doubt, more than the others approach towards a sufficient explanation; but even these can hardly be said to meet all the difficulties with which the subject is invested.

In objection to the side-movement theory, according to which the granite was forced against and on to the *hard* Quader, we have the fact that at Hohnstein, where one of the results of the explorations made at that place was to prove that the older rock overlies the sandstone to the extent of at least 900 feet, no curvature or dislocation of the strata is observable in the latter, parts of which are laid open to observation up to within a few feet of the intervening calcareous layers, in a ravine running out of the Polenzvalley, in a direction almost parallel with the granite border.   It is true the rock gives evidence of having been subjected to some action which has materially affected the character of the stratification in this locality; this action, however, must have ceased before the induration was complete; for the vertical lines of parting are continued regularly down through the strata as elsewhere, showing no fault, even to the extent of a few inches, in the general run of the beds.

Again, the layers of red and black clay, altogether more than 70 feet thick, which occur between the granite and calcareous conglomerate at Hohnstein, are separated by a well-defined line, and present no signs of having been disturbed, at least to anything like the extent which we might have expected to have been the case had these soft and thick beds been subjected to the enormous pressure which must have been exerted in pushing back the whole mass of hardened sandstone (more than 1000 feet thick), especially when we consider the broken and rugged faces of the over- and underlying rocks between which the clay is found.

According to the theory of Klipstein the granite region must have had for its southern border a line of cliffs running east and west for more than forty miles, and reaching to a height of at least 1000 feet above the bottom of the sea which washed it during the Cretaceous period.   These cliffs, generally nearly perpendicular, must in some

few places have overhung their base at least 900 feet—a state of things which the mind can hardly conceive to have been possible. There is, besides, the fatal objection to this theory, that it ignores altogether the existence of the Jurassic conglomerate and fossils at Hohnstein.

The hypothesis of Gumprecht has been disproved by the fact of fragments of granite, corresponding in every respect with the overlying mass, having been found imbedded in the conglomerate, thus setting completely at rest the question as to the comparative ages of the different rocks found at Hohnstein.

It will therefore, perhaps, be readily admitted that the phenomena observed along the line which separates the two formations indicate beyond a doubt that an upward and lateral movement of the granite all along that line* has taken place, in accordance with Cotta's theory; but so extensive a lateral movement of the granite against and over a mass of stratified *hard* rock, of more than a thousand feet thick, could hardly have taken place without bending or crushing the strata to a considerable distance from the line of contact; while the fact is that, at Hohnstein and other places along the border where the Quader is laid open to observation, the strata are found to be but little disturbed, and are generally horizontal to within a few feet of the granite.

If, instead of supposing, with Cotta, the sandstone to have been deposited and converted into rock before the disturbance to which the elevation of the Lusatian granite is due, we admit *that the elevation of the latter rock commenced before, and continued during, the deposition of the former, and that the induration of the sandy deposit was not completed until the granite had attained to nearly its present relative elevation and position*, then all the greater difficulties of the case disappear.

Whatever disturbance may have taken place in the mass of soft sand in close proximity to the granite, the consequences of that disturbance would not communicate themselves to any distance through it, nor influence, save in a very slight degree, the regularity of deposition of the upper strata; for the lateral movement being exceedingly slow, the quantity of sand displaced during a given period by that movement would be infinitely small, as compared with the duration of that period.

At the same time we should not be justified in asserting that no alteration whatever would take place in the character and appearance of the rock in consequence of this disturbance; for the particles of sand displaced immediately by the intruding granite would displace others, and so on to a certain distance, forcing them into closer contact throughout that distance, and driving the clayey matter from between the layers into the mass. The rock in these localities would thus be rendered more compact and the lines of stratification less evident.

* This line marks one of the most extensive fissures, in one direction, known, it being traceable from Oberen, near Meissen, to Glatz, in Silesia, a distance, nearly east and west, of more than 150 statute miles.

The disturbance of the sand would be less or greater, according as the face of the granite was more or less parallel with the line of motion; for, supposing the two to coincide at any point along the line, then the latter would merely slide, as it were, along the face of the sandy layers, and that of the older strata, causing little or no disturbance; should, however, the face of the granite be more vertical than the line of movement, then the effect would be a lifting up and lateral displacement of the deposit lying against it.

An *entire* absence of any signs of disturbance in the Quader, near the border, could, however, be possible *only* in the case that its induration commenced subsequently to the period of upheaval of the granite; but that this induration was completed before that rock reached its present relative elevation, is proved by the fact that the sandstone presents all along its border evident and unmistakeable indications of having been subjected to lateral pressure.

This latter fact is of great significance, as going far towards accounting for the crushed condition and inclination of the strata which lie against those parts of the granite border which are perpendicular, or nearly so, and the almost total absence of these phenomena at Hohnstein and other parts, where the contact-line dips at a small angle from the sandstone. The above-stated fact will also go far towards accounting for the presence (at the surface) of the Jurassic rocks at Hohnstein and Hinterhumsdorf, and their absence at all other parts along the line. I will proceed to state the grounds which my opinion with regard to this fact is based.

At those places where the calcareous rock is found, the granite overlies the newer rocks to a considerable extent, while at most other parts of the line the granite and sandstone abut against each other almost vertically, to the height of, at least, 500 feet. It would thus seem probable that, prior to the commencement of the deposition of the latter, a long range of cliffs may have formed the northern shore of the Jurassic sea at this place, against which the strata of that period were deposited.

If this be admitted, three different epochs may be supposed to be represented at a part of the border where the transverse direction of the fissure approximates, more or less, to that of the moving force, and the same epochs at a part where the fracture is vertical[*].

The continued advance of the granitic mass through the *loose* sand at some parts of the border would have no other effect than that of increasing in some degree the compactness of the latter in the immediate vicinity of the disturbing agent; but from the moment that the Quader had become *completely indurated* throughout its depth, the case would be altered entirely; the latter would now be crushed back, and the ends of the strata in contact with the granite would be lifted up through the whole extent of the subsequent upheaval.

At those parts, however, where the granite overlaps the strata, they would be very slightly disturbed; the granite would slide over

[*] I consider the force to have been exerted in a horizontal and north and south direction.

them, as it were, and the only result of its movement would be to grind the faces of the rocks and any body which might have found its way between them. The elevation of the Jurassic fragments at Hohnstein, and at the one or two other places where they are met with, is most probably due to a configuration of the face of the granite at those parts favourable to such a result. The phenomena presented are such as might be expected under the circumstances : we have immediately below the granite a bed of clay resulting from the attrition and decomposition of that rock, then a mass of Jurassic conglomerate, and below this, and next the Quader, a thicker bed of sandstone-conglomerate resulting from the grinding off of the ends of the strata of that rock.

This extensive deposit of sandstone may, I think, be referred to the agency of a strong under-current, running from north to south, through an arm of the sea, which must have existed at this place during the Cretaceous period. This current, sweeping over the range of submarine hills which extended in an east and west direction for about 140 miles, rising gradually from the north and terminating in a precipitous face to the south, through the whole of that distance would bring with it the detritus brought down by the melting of glaciers and snow in the higher latitudes, and by rivers along the shores. This detritus would be naturally deposited in the dead water which would lie to the southward of the ledge ; and this deposit would stretch further and further south as the granite wall rose higher and higher, until the new relations between land and sea, brought about by the subsequent geological revolutions, had forced the waters to find some other channel.

4. *The conditions under which the Basalt is met with.*—The Erzgebirge chain, of which the Saxon Switzerland may be regarded as a prolongation, seems to owe its present elevation to a succession of upheavals of the granite, gneiss, and schists lying to the north of a long fracture running in an E.N.E. direction from the Fichtelgebirge to beyond the Elbe at Tetschen, in Bohemia, and probably joining the one treated of in the foregoing section, under a very acute angle at some point E.N.E. from that place.

Rising with an easy slope from the north-west to a height in some parts of about 3000 feet, it falls suddenly to the south-east, along its whole length, leaving a well-defined ridge throughout. An ideal section of the chain is given in Cotta's ' Deutschland's Boden.'

The eruption of the basalt must have taken place at a comparatively recent period, as it has not only broken through the granite and schists of the main portions of the chain, but also through the sandstone of the Saxon Switzerland, which forms its north-eastern extremity[*]; and it is a significant fact that, although it comes to

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[*] The summits of four of the most elevated points in the Erzgebirge are basalt—namely, Erbner Höhe, 3172 feet (French), Bärenstein, 2740 feet, Pohlberg, 2548 feet, and the Scheibenberg, 2443 feet; between the basalt and the primary rocks at each of these places there occur, according to Gutbier, layers of Tertiary clay and gravel. This would bring the period of the last general upheaval in this region down to a time at least as recent as the breaking through of the basalt.

the surface in many parts of that region, it is nowhere to be met with in the ravines or valleys, or even in the lower parts of the valleys, but either at or near the top of the rocky heights, thus going far toward proving, first, that the deposit reached originally a height throughout equal at least to that of the highest of these at the present day, and, secondly, that these isolated eminences owe their relatively superior elevation indirectly to the indurating influence of the igneous rock, which rendered these parts more invulnerable to the action of the denuding forces which swept away the softer portions around them.

The following are among the most remarkable places where the basalt comes to the surface :—

1. The Schneeberg, 2200 feet; the volcanic rock protrudes at both sides of the rocky crest of this mountain, at a height of 1817 feet.

2. The Larger Zschirnstein, 1720 feet; blocks of dolerite are found at the very top of this mountain, coming through the Quader.

3. The Larger Winterberg, sandstone up to 1550 feet, surrounded by a basaltic crest reaching to 1716 feet; fragments of granite have been found imbedded in the basalt of this place.

4. The Lesser Winterberg, 1520 feet.

5. The Rosenberg, sandstone up to 1550 feet, crowned by a peak of basalt 1910 feet.   (The measures are all in French feet.)

The strata are quite horizontal and undisturbed up to within a very short distance of the igneous rock—a fact which would seem to favour the hypothesis that the eruption of the latter must have taken place prior to the complete induration of the sandstone.   Another circumstance seems also to favour this view; and that is, that the lines of fissure which extend throughout the region generally are not found to run up to the basalt, the Quader in its vicinity losing the tendency to break up into cubical blocks, and offering a fracture more similar to that of granite.

A remarkable peculiarity in the sandstone occurs at the eastern foot of the Gorischstein.   Here the basalt comes to the surface at a height of about 1230 feet, and is quarried for road-making; in its immediate vicinity the sandstone is found in small regular prismatic blocks, from $\frac{1}{4}$ inch up to 2 inches in diameter, with four or five sides, and about 6 or 8 inches long; at the distance of 100 yards the main rock offers no signs of having been disturbed, or subjected to the action of heat.

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

FOSSIL ANIMALS *and* GEOLOGY *of* ATTICA. By ALBERT GAUDRY.
Part I.—FOSSIL ANIMALS.

[Animaux Fossiles et Géologie de l'Attique. Par M. Gaudry. Part I. Animaux
Fossiles. 4to. Paris, 1867. Plates 60.]

IN the first part of this work, M. Gaudry describes the remark-
able association of different species of Mammals obtained out of
a deposit, probably of Upper Miocene age, near Pikermi, in Attica.
He conducted the exploration in person, living in a tent, during
the summers of 1856-7 and 1860; and his labours have been
rewarded by the most complete suite of organic remains that has
ever been brought before the world of science, not even omitting
that of the Sevalik Hills. These ample materials he has most rigo-
rously analyzed; and after comparing the remains, bone by bone,
with those of living Mammals, he has not only noted the points of
difference, but also has been the first naturalist to attach due im-
portance to the points of agreement that link species with species,
genus with genus, and order with order.

The section exposed during his excavation is as follows :—Vege-
table soil 2 metres; conglomerate 4 metres; brickearth, with few
bones, 2 metres; ossiferous bed with contents lying pell-mell, but
with the skeletons entire in some cases, of irregular thickness, 3
metres; limestone containing recent shells forms the basis.

The following is a list of the animals discovered :—

Order QUADRUMANA.

1. Family MACACIDÆ. Species *Mesopithecus Pentelici*, Wagner. A
   small Old-World Monkey, allied to *Semnopithecus* in the shape
   of its head, in its limbs to *Macacus*. The abundant remains
   show that the animal lived in troops. Number of individuals
   found, 25.

Order CARNIVORA.

2. Family SIMOCYONIDÆ. Species *Simocyon diaphorus*, Gaudry. In-
   termediate between *Ursus* and *Lupus*; allied to the former in its
   elongated lower true molar 2, to the latter in its lower pre-
   molar 4 and molar 1. It was an omnivorous animal, of about the
   size of a small Panther. Number of individuals found, 2. Fo-
   reign locality—Upper Miocene of Eppelsheim.

3. Family MUSTELIDÆ. Species *Mustela Pentelici*, Gaudry. Rather larger than the existing *Mustela* of Canada, and possessed of a longer jaw than the living Mustelines; characterized by a diastoma between premolars 2 and 3.

Dental formula i 3., c, p m 1. 2. 3. 4., m 1. 2.

Number of individuals 1.

4. Family MUSTELIDÆ. Species *Promephitis Lartetii*, Gaudry. Closely allied to the Mephitis. Less carnivorous than the Martins and Stoats, more so than the Otters and Moufettes.

Dental formula $\dfrac{\text{i 1. 2. 3., c, p m 3. 4., m 1. 2.}}{\text{i 1. 2. 3., c, p m 3. 4., m 1. 2.}}$

Number of individuals 1.

5. Family VIVERRIDÆ. Species *Ictitherium robustum*, Gaudry, = *Thalassictis*, Gervais and Nordmann, = *T. viverrinus* of Wagner. An animal far larger than any of the living Viverrines, possessed of enormous masticatory powers, and resembling in habits, most probably, a small dog-like *Hyæna brunnea*.

Dental formula $\dfrac{\text{i 1. 2. 3., c, p m 1. 2. 3. 4., m 1. 2.}}{\text{i 1. 2. 3., c, p m 1. 2. 3. 4., m 1. 2.}}$

Number of individuals 9. Foreign locality—marine deposit at Kishinew, in Bessarabia, which contained thirty-two species of marine shells referred by M. d'Orbigny to the age of the Faluns of Touraine and Bordeaux, and therefore Miocene.

6. Family VIVERRIDÆ. Species *Ictitherium hipparionum*, Gaudry, = *Hyæna hipparionum*, Gervais. A much larger animal than the preceding. Number of individuals 2. Foreign localities—Upper Miocene of Cucuron in Vaucluse, and of Baltavar.

7. Family VIVERRIDÆ. Species *Ictitherium Orbignyi*, Gaudry. Smaller than the other species of the same genus; intermediate in size between the Civet and the Genet of India. Number of individuals 4.

8. Family HYÆNIDÆ. Species *Hyæna eximia*, Roth and Wagner. Slightly larger than living Hyænas. In its dentition intermediate between *H. brunnea* and *H. crocuta*.

Dental formula $\dfrac{\text{i 1. 2. 3., c, p m 1. 2. 3. 4., m 1.}}{\text{i 1. 2. 3., c, p m 1. 2. 3. 4., m 1.}}$

Number of individuals 3. Foreign locality: Upper Miocene of Baltavar.

9. Family HYÆNIDÆ. Species *Hyæna (Lycyæna) chœretis*, Gaudry and Lartet. Closely allied to the striped Hyæna.

Dental formula i 1. 2. 3., c, p m 1. 2. 3. 4., m 1.

Number of individuals 2.

10. Family HYÆNIDÆ. Species *Hyænictis Græca*, Gaudry. About the size of the Spotted Hyæna. It possesses four premolars in the lower jaw. Number of individuals 1. Foreign locality— Upper Miocene of Baltavar. The last two species form a connecting link between the families of Hyænidæ and Viverridæ,

being allied to the latter in the presence of the first premolar of the lower jaw, to the former in the non-development of the lower true molar 2. The passage, indeed, is gradual from *Viverra* proper through the genus *Ictitherium, Hyænictis* (*Hyæna*) *chœretis* into *Hyæna* proper.

11. Family FELIDÆ. Species *Machairodus cultridens*, Kaup. Slightly larger than any existing *Felis*. " Le roi des animaux de cette époque " (Miocene). Number of individuals 3. Foreign localities:—Upper Miocene of Baltavar and Eppelsheim ; Pliocene of Perrier and the Val d'Arno ; [Pleistocene of Kent's Hole.]

12. Family FELIDÆ. Genus *Felis*. At least of the size of the Jaguar. Number of individuals 2.

13. Family FELIDÆ. Genus *Felis*. Size of Panther of Africa, but of more slender build. Number of individuals 2.

14. Family FELIDÆ. Genus *Felis*. Intermediate in size between *Panther* and *Caracal*. Number of individuals 1.

15. Family FELIDÆ. Species *Felis Attica*, Gaudry. Larger than the living Cat. Number of individuals 1.

Order RODENTIA.

16. Family HYSTRICIDÆ. Species *Hystrix primigenia*, Gaudry. A Porcupine closely allied to the *H. cristata* of Europe. A species has also been found in the Pliocene of the Val d'Arno, in Sicily, and in the environs of Issoire. Number of individuals 2.

Order EDENTATA.

17. Family ANCYLOTHERIDÆ. Species *Ancylotherium Pentelici*, Gaudry. Allied to *Macrotherium Sansaniense*, Lartet. A huge Edentate, larger than *Rhinoceros*, to which animal it is allied, as to the *Mastodon* and *Pangolin*. Number of individuals 3.

Order PROBOSCIDEA.

18. Family ELEPHANTIDÆ. Species *Mastodon Pentelici*, Gaudry and Lartet. Size of small living Elephant. The milk-molar 2 has two collines, as in the Tetralophodons ; and the milk-molar 3 has three collines, as in the Trilophodons. Number of individuals 2.

19. Family ELEPHANTIDÆ. Species *Mastodon Turicensis*, Schinz,= *M. tapiroides* of Blainville. Size of large Elephant. Number of individuals 2. Foreign localities—Middle Miocene of Touraine, San Isidro, Winterthur, and Odessa.

20. Family DINOTHERIDÆ. Species *Dinotherium giganteum*, Kaup. Much larger than any living animal. In its limbs allied to the Elephant, in its head to the Lamantin. Number of individuals 1. Foreign locality—Upper Miocene of Eppelsheim.

21. Family DINOTHERIDÆ. Genus *Dinotherium*. Of the size of the living Elephant. Number of individuals 1. Foreign locality— Middle Miocene of Touraine.

Order PERISSODACTYLA.

22. Family RHINOCERIDÆ. Species *Rhinoceros pachygnathus*, Wagner.

Of the size of *Rhinoceros simus* of Africa, without a cloison, possessed of two horns. In the form of its head allied to *Rhinoceros bicornis*, in the shape of its limbs to *R. simus.*

Dental formula, $\mathrm{D\,M}\ \dfrac{4}{4}\quad \dfrac{\text{i 0?, c 0, p m 1. 2. 3. 4, m 1. 2. 3.}}{\text{i 1., c 0, p m 1. 2. 3 4, m 1. 2. 3.}}$.

Foreign locality—Upper Miocene of Eppelsheim.

23. Family RHINOCERIDÆ. Species *R. Schleiermacheri*, Kaup. Closely allied to the Rhinoceros of Sumatra. Foreign locality—Upper Miocene of Eppelsheim.

24. Family RHINOCERIDÆ. Species *Rhinoceros* — ? Its head is larger than that of any known species.

25. Family RHINOCERIDÆ. Species *Acerotherium* — ? The presence of this species is indicated by only a lower jaw.

Dental formula $\dfrac{\text{i 1. 2. 3., c 1, p m 2. 3. 4, m 1. 2. 3.}}{\text{i 1. 2. 3., c 1, p m 2. 3. 4, m 1. 2. 3.}}$.

The bones vary in size to such a degree that the animal has received no less than fourteen distinct specific names, which the author has proved to be invalid.

26. Family RHINOCERIDÆ. Species *Leptodon Grœcus*, Gaudry. This remarkable animal, known by only one lower jaw, containing p m 1. 2. 3. 4., m 1. 2. 3., forms a link between *Rhinoceros* and *Palæotherium.* The last molar is trilobed.

27. Family EQUIDÆ. Species *Hipparion gracile*, Christol, = *Hippotherium* = *Equus primigenius*, Wagner. The size of a Zebra. Number of individuals 80. Foreign localities—Eppelsheim; Cucuron, in Vaucluse; Visan, near Perpignan; in the marine sands of Montpellier; in the basin of the Rhone; at Alcoy and Concud, near Téruel, in Spain; at Sutton, in Suffolk; in Würtemberg; Sternberg; Bessarabia ?; in the Sevalik Hills; and in Nebraska.

Order ARTIODACTYLA.

28. Family SUIDÆ. Species *Sus erymanthius*, Roth and Wagner. A gigantic wild Boar with its head one-third larger than in the existing animal.

Dental formula $\dfrac{\text{i 1. 2. 3., c 1, p m 1. 2. 3. 4, m 1. 2. 3.}}{\text{i 1. 2. 3., c 1, p m 1. 2. 3. 4, m 1. 2 3.}}$.

Number of individuals 12. Foreign locality: Upper Miocene of Baltavar.

Order RUMINANTIA.

29. Family GIRAFIDÆ. Species *Camelopardalis Attica*, Gaudry and Lartet. About the same size as the existing species, but rather more slenderly built. Number of individuals 3.

30. Family HELLADOTHERIDÆ. Species *Helladotherium Duvernoyi*, Gaudry. A hornless species allied to the Giraffe, Antelope, and Deer. The teeth resemble in form those of the Antelope, and they are without an accessory column. The animal was stouter than any living ruminant, but not so lofty as the Giraffe.

Number of individuals 11. Foreign locality—Upper Miocene of Baltavar and of the Sevalik Hills.

31. Family ANTILOPIDÆ. Species *Palæotragus Rouenii*, Gaudry. A ruminant with horns recurved, oval in section and divergent. Molars without an accessory column, which, however, is present in lower true molars 1 and 2. It is allied to the Giraffe, Deer, and Antelope. Number of individuals 3.

32. Family ANTILOPIDÆ. Species *Palæoryx Pallasii*, Gaudry. A subgenus of Antelope, allied to the Oryx. The accessory column is present in the upper true molars 2 and 3. It has no larmiers. Horncores recurved and oval in section. It is the largest of the Antelopes, and has *Oryx leucophœus* for its nearest living ally. Number of individuals 3.

33. Family ANTILOPIDÆ. Species *Palæoryx parvidens*, Gaudry. One-third smaller than the preceding, while the horncores are quite as large. Number of individuals 2.

34. Family ANTILOPIDÆ. Genus *Antilope*. The animal is only known by one gigantic horncore.

35. Family ANTILOPIDÆ. Species *Tragocerus Amaltheus*, Gaudry. Of the size of a small Deer, allied to the Goats in the shape of its horncores; in other respects to the Antelopes. No larmiers. Horncores compressed and triangular in section at the base. The bones present many variations which, were it not for the gradations observable in a large series, might be considered differences of specific value. Number of individuals 50. Foreign locality—Upper Miocene of Cucuron.

36. Family ANTILOPIDÆ. Species *Tragocerus Valenciennesi*, Gaudry. It differs from the preceding by its slightly smaller size and less compression of the horncores. Number of individuals 2.

37. Family ANTILOPIDÆ. Genus *Antilope*. This species is based on a skull of the same form as that of *Tragocerus Amaltheus*; but the horncores are different.

38. Family ANTILOPIDÆ. Genus *Antilope*? This species has not been determined.

39. Family ANTILOPIDÆ. Species *Palæoreas Lindermayeri*, Gaudry. A subgenus of *Antilope*, with spirally twisted straight horncores in adult; allied to *Oreas* and to *Gazella*. In the young the spiral is not deeply impressed on the horncores; accessory column present in upper molars. The animal is larger than *Gazella dorcas*. Number of individuals 36.

40. Family ANTILOPIDÆ. Species *Antidorcas? Rothii*, Gaudry. This species is based on a pair of horncores and a frontlet; they are spirally twisted, and together assume a lyrate form. Number of individuals 5.

41. Family ANTILOPIDÆ. Species *Gazella brevicornis*, Gaudry. About the size of the *Gazella dorcas*, from which animal it differs in the presence of accessory columns in the teeth, and in the thickness of the horncores. It is closely allied to *Antilope deperdita*, Gervais. Number of individuals 50. Foreign locality—Upper Miocene of Baltavar, Cucuron, and Concud.

42. Family Moschidæ. Species *Dremotherium Pentelici*, Gaudry. A small hornless ruminant of about the size of a Musk Deer and allied to the Dremothere of Eppelsheim. Number of individuals 2.

43. Family Moschidæ. Species *Dremotherium* — ? ; known only by a lower jaw larger than that of the Gazelle, smaller than that of the Sheep or Goat.

Aves.—Order Gallinæ.

44. Family Gallinaceæ. Species *Phasianus Archaici*, Gaudry. One-quarter larger than the common Pheasant. Number of individuals 2.

45. Family Gallinaceæ. Species *Gallus Æsculapii*. A bird of the size of a very small Cock. Number of individuals 2.

46. Family Gallinaceæ. Species doubtful. A bird of the size of a Cock. Number of individuals 2.

Order Grallatores.

47. Family Cultirostres. Species *Grus Pentelici*, Gaudry. A bird larger than the Ash-coloured Crane. Number of individuals 2.

48. Family Cultirostres. Species ? A wader; known only by a humerus of the size of that of the largest Stork.

Reptilia.—Order Chelonia.

49. Family Chelonia. Species *Testudo Marmoreum*. A Tortoise of the same size as *T. marginata,* now living in Greece. Number of individuals 2.

Order Sauria.

50. Family Monitores. Species *Varanus* — ? This species is based on a vertebra indicating an animal of the same size as the large Monitor now living in Africa and Asia.

Along with these remains M. Gaudry met with one isolated specimen of *Helix.*

The whole of the animals enumerated belong to 35 genera, of which 20 are extinct, and to 51 species, of which all are also extinct. To the list of Mammals the author also adds *Chalicotherium*, of the size of a Rhinoceros, and the genus *Orasius* proposed by Dr. Wagner.

This remarkable assemblage of animals, all of which are utterly extinct, points out the geological age of the Brick-earth of Pikermi to have been Upper Miocene or Early Pliocene. The fauna is for the most part African in type, and proves that Greece was most intimately connected with the mainland of Africa during Miocene times. In the deposit of parallel age at Baltavar and Eppelsheim, no African types have been found,—a fact which may be accounted for on the hypothesis that those formations contain the remains of a more northern group of Mammals, whence the inference may be drawn that Europe in Miocene times was divided into zones of life, as in the Pleistocene and recent periods. The development of Mammals in Europe in point of size reached a maximum in the animals of Pikermi ;

and some of them form links between different genera. The genus *Hipparion* forms a link binding the genus *Equus* to the genus *Rhinoceros*; for its members have small hoofs on either side of the principal one, as in the latter genus, a peculiarity which has been observed by several eminent naturalists in malformed horses. According to this view the malformation in the living horse would simply be a recurrence to ancestral types of the early Pliocene and later Miocene. The *Ictitherium* also is a link between the Hyænidæ and the Viverridæ, and is considered by the author to be the ancestor of all the diversified forms of the Hyænidæ. In like manner *Rhinoceros pachygnathus* has handed down its characters to two collateral branches, *R. simus* and *R. bicornis* of Africa. In fine, the intermediate character of the fauna of Pikermi, allied on the one hand to preceding Eocene and Miocene types, and on the other to more specialized and more recent Mammals of the Pliocene and Pleistocene epochs, as well as to those now living, is considered by M. Gaudry to be explicable only on the theory of descent with modification, proposed by the author of the ' Origin of Species.' [W. B. D.]

On the Coal-Plants of Ostowan and Rossitz (Moravia). By Mr. D. Stur.

The deposits of these localities have lately been stated by Prof. H. B. Geinitz to belong to the Carboniferous period, and to be analogous to the strata of Wettin, Jlefeld, Stockheim, and Ebendorf. The vegetable remains are distributed in them as follows :—

Roof of the 1st (uppermost and principal) Coal-bed.

Asterophyllites equisetiformis, *Schloth.*, sp.	Stigmaria ficoides, *Brongn.*
Neuropris auriculata, *Brongn.*	Sphenopteris artemisiæformis, *Sternb.*
—— Loshi, *Brongn.*	Lycopodites piniformis, *Schloth.*
Cyatheites dentatus, *Brongn.*	Odontopteris Schlotheimi, *Brongn.*
—— arborescens, *Schloth.*, sp.	Lepidophyllum majus, *Brongn.*

Foot of the 1st Bed.
Alethopteris Serli, *Brongn.*

Roof of the 2nd Bed.

Asterophyllites equisetiformis, *Schloth.*, sp.	Cyatheites arborescens, *Schloth.*, sp.
Odontopteris minor, *Brongn.*	—— oreopteridis, *Sternb.*, sp.
Noeggerathia palmæformis, *Göpp.*	Cardiocarpon marginatum, *Artis*, sp.
Annularia longifolia, *Brongn.*	Annularia sphenophylloides, *Zenken*, sp.

Third (Lower) Bed.

Equisetites infundibuliformis, *Brongn.*	Annularia longifolia, *Brongn.*
Sphenophyllum oblongifolium, *Germ.*	Asplenites (Sphenopteris) Virleti, *Brongn.*
Odontopteris Brardi, *Brongn.*	
Cyatheites dentatus, *Brongn.*	Dictyopteris Brongniarti, *Gutb.*
—— arborescens, *Schloth.*, sp.	Odontopteris Schlotheimi, *Brongn.*
—— argutus, *Brongn.*, sp.	Noeggerathia palmæformis, *Göpp.*
Annularia sphenophylloides, *Zenken*. sp.	

It may be remarked that *Sigillaria* and *Calamites* are completely absent, and that ferns are by far predominant. This is the reason why Prof. Geinitz ranks the coal-beds of Oglossan and Rossitz among his "fifth or newest" zone of Carboniferous deposits; and, in fact, the Rossitz strata are immediately and conformably overlain by those of the New Red Sandstone.   [COUNT M.]

On FOSSIL CORALS. By Prof. REUSS.

[Proceed. Imp. Acad. Vienna, July 18, 1867.]

REMAINS of corals are contained in three of the subdivisions of the older Tertiaries of the south-eastern Alps, established by Prof. E. Suess, but most abundantly in the more recent of them, the strata of Castelgomberto, where eighty-two species are found, of which sixteen only are known to occur in other localities. Their imperfect state of preservation has proved an insurmountable obstacle to the determination of a large number of these remains. The sixteen previously known species have been found also in the calcareous Nummulitic marls of Oberburg (Styria). Some of the forms from the latter locality have not been noticed in the Castelgomberto strata, —a fact which may probably indicate that they belong to a somewhat lower horizon. As a whole, the strata of Castelgomberto are undoubtedly referable to the same geological horizon as those of Oberburg, and the lower marine sands of Weinheim, in the Mayence basin. Their coral-fauna, however, is totally different (a necessary consequence of their different modes of deposition)—the strata of the Vicentin being the remains of gigantic coral-reefs, while the sands of the Mayence basin supported only a few small solitary corals. Another locality in the same horizon is Gaas, in the south of France, whose coral-fauna requires further elucidation. Several of the Gaas species are identical with those of Castelgomberto; and it is probable that deposits of the same age may be found overlying the older Tertiaries of the Hala mountains in Eastern India. Repeated examinations of the badly preserved coral-remains from Waschberg (about five Austrian miles N.N.E. of Vienna) have enabled the author to determine the specific identity of some of them with those of Castelgomberto.   [COUNT M.]

Bone-Caves in Portugal. By Senhor J. F. N. Delgado.

[Commissão Geologica de Portugal. Estudos Geologicos. Da Existencia do Homen no nosso solo em Tempos mui remotos provada pelo estudos das cavernas. Primeiro opusculo. Noticia ácerca das Grutas da Cesareda. Por J. F. N. Delgado. Com a versão em Francez por M. Dalhunty.]

In this first instalment of a work on the former existence of man in the caves of Portugal, Senhor Delgado publishes the results of his labours in the caves in the Jurassic limestone of Cesareda. After entering into the general question of the origin of caverns, he describes the contents of the three which he explored. The first of these, the Casa da Moura, contained deposits of two very distinct ages, which together varied in thickness from two to four metres. The inferior rested on the stalagmite, and consisted of sand mixed with fragments of rock. It yielded fragments of charcoal, one bone, and many flint implements. A human skull and lower jaw were also obtained from its deepest part; but as the surrounding matrix had been disturbed, they were probably buried at a time subsequent to the formation of the deposit. The other bones and teeth indicated the presence of the following animals :—No less than five species of *Felis*, two species of *Canis* (*C. Lupus*, and a form larger than any fox known to the author), a species of large carnivore, a species of *Cervus*, *Hypudæus amphibius*, *Lepus cuniculus*, and *Erinaceus communis*. The remains of the rabbit were most abundant, and were for the most part broken. None of the bones of the latter had been subject to the action of fire, nor did they present any trace of gnawing. The bones, charcoal, and flint implements the author considers to have been introduced by man, who inhabited the cave at some early period.

The upper deposit is composed of a sandy loam, containing a large quantity of stones and a vast quantity of objects fabricated by man, such as hatchets of polished stone of the Celtic type, of flakes, and other instruments of flint, bone, and antler; many fragments of black pottery coarsely made with bits of calcareous spar, of splinters of flint, of small fragments of celts, and of plates of schist with designs, which perhaps may have been used as amulets. There were also many shells of *Helix nemoralis* and cockles, some of which were pierced for suspension. Fragments of charcoal were scattered throughout the matrix, and adhered in small patches to some of the pottery and to the pebbles, which had been probably used in constructing fireplaces. In the lowest portion of the deposit a bronze arrow-head was buried. The most abundant remains were those of man; they were to be counted by thousands, and were all in a condition more or less fragmentary, and so scattered that it was impossible to construct one perfect skeleton out of them. Some bones were far more abundant than others; but the teeth, which for the most part belonged to young or fully grown adults, were particularly abundant. The long bones had lost for the most part their articular ends, and presented longitudinal fractures; and some of them had been cut and scraped.

The spongy bones, such as the vertebræ and ribs, were very rare. Their condition seems to indicate that the men to whom they belonged had been eaten for food. The pottery bore an ornament of continuous lines, or of rows of dots. The associated animals consist of the bat, the wolf, the fox, and a species of *Canis*, the wild cat, the dormouse, the rabbit, the horse, deer, and the sheep, or goat. This assemblage of the remains of different animals associated with the traces of man's handiwork is accounted for by the author on the supposition that the cave had been used as a burial-place by a tribe of cannibals, who slaughtered their slaves and prisoners, and who buried the relics of their funereal feasts with the ashes of the dead, and with the implements that he was to use in a world of spirits.

The author explored also two other caverns in the neighbourhood, that of Lapa Furada, and of the Cova da Moura ; both furnished remains analogous to those of the upper deposit of the Casa da Moura. From Lapa Furada he obtained a fragment of a lower jaw, which he refers to the *Ursus arctos*. [W. B. D.]

On a SPECIES *of* FELIS, *of* URSUS, *and of* RHINOCEROS, *from a* BONE-CAVE *in the* MARITIME ALPS. By M. E. LARTÊT.

THE well-known researches of M. Bourguignat in 1866 have furnished M. Lartêt with the subject matter of this most important essay. There were associated in the Cavern of Mars, situated eight kilometres from Vance, the skull of a bear, that of a lion, the remains of rhinoceros, *Sus*, *Lepus*, and two species of deer.

Ursus Bourguignati (Lartêt).—The bear's skull differs remarkably from all the living members of the genus, except the *Ursus maritimus*, and from all the fossil ones, with the exception of the *Ursus priscus* of Goldfuss and the *Ursus planifrons* of Mr. Denny. From these three also it is separated by points of difference, which M. Lartêt believes to be of specific value. In the *U. Bourguignati*, the palate is much narrower than in *U. priscus*. The two series of molar teeth do not converge so much ; and their number is six on each side, on account of the persistence of the two small simple premolars, of which one is situated in front of premolar 4, and the other immediately behind the canine. In other respects there is the same dental arrangement as in *U. priscus*, except that the diastema between the two small premolars is greater. The carnassial, or premolar 4, has its antero-external lobe higher and its internal talon is less developed. The differences between the true molars are less strongly marked, and therefore more difficult to determine. A comparison with *Ursus planifrons* shows that the palate of that animal is proportionally much wider than in the French species. Nothing can be predicated of the form of the teeth, because they are all wanting in the former skull. In the polar bear the palate is narrower than in the French species, the two rows of molars have the same numerical formula (but instead of converging in front, as

in the two preceding fossil species, with which *U. Bourguignati* has been compared, they approach one another behind; the diastema between the two simple premolars is longer, and premolars 3, 4, true molars 1, 2, occupy less space in the alveolar edge, while their transverse diameters are greater. In the carnassial tooth, the internal talon is smaller, and instead of being raised by a stout tubercle, it presents normally only low rounded bosses on a base but slightly extended backwards.

Felis leopardus? var. *fossilis* (Lartêt).—The skull of the *Felis* is about the size of that of the largest panthers of Africa. It approaches in its dimensions the skull of the variety living in Morocco, but still more closely the variety now found at the Cape of Good Hope. There are, however, appreciable differences observable between the fossil and the recent form. The canines of the fossil are longer, and their sillons are deeper. The lateral incisor has a stronger, the second a weaker fang. The small mono-fanged premolar has its crown smaller, less compressed, and disposed more obliquely to the alveolar edge; it is also nearer the canine and isolated somewhat from premolar 3. The latter is stouter than in the Cape leopard, thicker behind, where its basilar cusp rests on a stoutly developed talon. The accessory anterior is situated more on the inside. The fourth premolar, or carnassial, is equally larger in its proportions; its talon is less detached from the anterior blade than in the existing leopard. The true molar was implanted by two fangs; but as its crown is broken, it is impossible to say whether it presented any differences. In the panther of Morocco, the space occupied by the molar series is the same as in the fossil. The small anterior premolar has its crown directed at a greater angle to the alveolar border, and the premolar 3 has a greater antero-posterior extent, and is without the small anterior accessory cusp.

These differences of proportion do not seem to M. Lartêt sufficiently important to prove that the *Felis* of the Cavern of Mars belongs to an extinct species.

Rhinoceros Merkii (Kaup).—Associated with the two preceding skulls were the remains of a Rhinoceros, which have led M. Lartêt to a most important inference about the nomenclature of one of the four Pleistocene species found in Great Britain. In the year 1839[*], Jäger figured, under the name of *R. Kirkerbergensis*, teeth found in Baden and Würtemberg; two years afterwards, in 1841, Dr. Kaup[†] determined the species, and changed its name into *R. Merkii*. In 1846[‡], Professor Owen described the remains of a Rhinoceros with a demicloison, from Clacton, as belonging to *R. leptorhinus* of Cuvier, or the Rhinoceros without a cloison. Duvernoy proposed provisionally, in 1853 [§], for the remains at Clacton the name of *R. protichorhinus*. About the same time M. Gervais[||], lighting on the so-called *R. minutus* of the cave of Lunelviel (described in 1834 by MM. de Serres, Dubreuil, and Jeanjean), imposed the name of *R. Lunellensis.*

[*] Foss. Säug. Würt. 1839, p. 179, tab. xv. figs. 31, 32, 33.
[†] Akten der Urwelt, 1841, p. 6, tab. i., ii.
[‡] Brit. Foss. Mamm. 1846, p. 356, figs. 131–141.
[§] Arch. du Mus. d'Hist. Nat. 1853, t. vii. p. 69.
[||] Zool. et Pal. Franc. 1re edit. p. 48.

In the same year M. Pomel* described the remains of *R. Merkii,* which were found in certain deposits in Velay, under the name of *Atelodus leptorhinus.* M. Aymard†, in 1855, confused the remains of four species of Rhinoceros together, and described *R. Merkii,* with some others, under the name of *R. mesotropus.* Lastly, Dr. Falconer ‡ assured himself, by personal examination, that the *R. leptorhinus* of Milan, described by Cuvier, could not be confounded with the *R. leptorhinus* of Clacton, described by Professor Owen ; for the latter he proposed the name of *R. hemitœchus,* in ignorance that this Rhinoceros à narines demi-cloisonnées was specifically identical with that described long before by Dr. Kaup, under the name of *R. Merkii.* The skull found at Daxland, near Carlsruhe, in 1807, was described, in 1864§, by Hermann von Meyer, under the name of *R. Merkii.* It is considered by M. Lartêt to belong to *R. etruscus.*

In working out the synonymy of this species, M. Lartêt has made it possible to trace the former range of the animal. In England its remains are found in the Lower Brick-earths of the Thames, and in sundry bone-caverns. In France they have been found in the fluviomarine sands of Montpellier, in the Pleistocene river-deposits, and also, though more rarely, in caverns ; in Germany, in the districts of Baden and Würtemberg ; in Italy, in the Pliocene deposits of Plaisantin, of the Milanais, and of Tuscany, as well as in the Pleistocene deposits of the environs of Rome. Teeth of the same species have been found in the caverns of Spain, and characteristic fragments have also been furnished by a cavern near Algiers, where they were buried with the remains of elephants (*Elephas Africanus* ?), of *Phacochœre,* of *Hyœna* (*H. spelœa* ?, *crocuta* ?), of panther, of porcupine, &c., together with human bones and worked flints. Thus the *habitat* of *R. Merkii,* verified up to the present time, is bounded on the one hand by the 51° of north lat., on the other by the 36°, with an extension in longitude of 17°. It is almost identical with the area occupied by *R. leptorhinus* (Cuvier) and *R. etruscus,* which are found equally in Germany, France, Spain, and England ; but it is much less than that of *R. tichorhinus,* the range of which in latitude is more than 30°, from the Pyrenees in the south to the 72nd parallel in Siberia, over almost 130° in longitude.

M. Lartêt believes that Europe, in the Glacial epoch, was possessed of a milder and more equable climate than that now found in the temperate regions, because it was broken up into islands during the time of the great Boulder-clay deposits ; that after the retreat of the glacial seas, it was exposed to the conditions of a continental climate ; that the summers were hotter and compelled the reindeer and musk-sheep to emigrate to Arctic latitudes better fitted for the needs of their life. On the other hand, the disappearance or extension of the hippopotamus, of certain species of rhinoceros, and of the great carnivora may have been the result of the increased cold of the winter.   [W. B. D.]

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* Cat. Mét. 1853, p. 79.
† Congrès scientifique de France, 1855, t. i. p. 270.
‡ Palæontographical Memoirs, 1868 (posthumous), vol. ii. p. 309 *et seq.*
§ Palæontographica, vol. xi. no. 5, p. 233, pls. xxxv.–xliii.

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

The SILURIAN CEPHALOPODS *of* BOHEMIA ; *and the* GROUPING *of*
ORTHOCERATITES. BY JOACHIM BARRANDE.

[Système Silurien du Centre de la Bohême, par Joachim Barrande. 1ère
Partie. Recherches Paléontologiques. Vol. ii. Céphalopodes, 3me série, pl.
245–350. Formes droites. Groupement des Orthocères.]

IN this series, M. Barrande describes the straight forms of the
Silurian Cephalopods of Bohemia, which include the genera *Bactrites*,
Bathmoceras, *Tretoceras*, and *Orthoceras*, this last division comprising
the subgenera *Huronia*, *Endoceras* and *Gonioceras*.

The three types *Bactrites*, *Bathmoceras*, and *Tretoceras* are repre-
sented in the Bohemian basin by only 4 species ; the subgenus
Endoceras furnishes only 2 representatives (*O. peregrinum* and *O.
novator*) ; while the subgenera *Huronia* and *Gonioceras* do not exist
in Bohemia.

Of 430 species or varieties of the genus *Orthoceras*, about one-half
are figured in the present series. It was the intention of the author
to propose a classification of this genus corresponding as nearly as
possible to the natural order of its species ; but the hope of being able
to complete his researches among some of the most important forms
at present but imperfectly known, and the difficulty of arriving at a
satisfactory arrangement, have decided him to propose a provisional
classification.

This classification consists in grouping the Orthoceratites accord-
ing to the most salient characters, either of general form or external
surface. These superficial or external characters are not founded
upon the variations of the principal organs of the mollusks, which
it would have been desirable to take as the basis of subdivision.
The almost invariable conformation of the aperture in *Orthoceras*
does not furnish any means of distinction derived from the form
of the head and of the arms or appendices ; and the inaccessibility
to observation of the elements of the internal structure of the
shell seems to reduce the grouping of this type to the employment
of the differences which are observable in their external appear-
ance. By this arrangement the species of this genus are first of
all separated into two principal sections, founded upon their general
conformation—the one having a short cone, with an apical angle
relatively large, the other having a prolonged cone with the apical
angle relatively small.

These two sections are distinguished by the names of short-coned
Orthoceratites (*Orthocères brévicônes*) and long-coned Orthoceratites
(*Orthocères longicônes*). To facilitate the study of the forms of the

latter section, it is subdivided into four categories, two provisional (*transitoires*) groups being adopted for all those forms which, having lost their shell, have lost, at the same time, the means of distinction. These categories are very unequal, some of them containing a very considerable number of Orthoceratites. But in comparing the species according to the most marked affinities of the ornaments of the surface, it is easy to subdivide each category into different groups, analogous to those which L. von Buch has established among the Ammonites, under the name of families.

It has been thought convenient by the author to leave out of these categories, which are principally founded upon the Orthoceratites of the Third Silurian fauna, the subgenus *Endoceras*, Hall, which contains species exclusively belonging to the Second fauna, and which is strongly characterized by the form of its siphon.

In the same way, the peculiar conformation of the siphon in the fossils originally named *Huronia* by C. Stokes confirms the author in maintaining them as a subgenus under the same denomination. The horizon from which these fossils come, in the Drummond Isle of Lake Huron, is stated to correspond with that of the Clinton and Niagara group in the State of New York—that is to say, to the first phase of the Third fauna. But this stratigraphical assimilation wants confirmation. The forms named *Gonioceras*, Hall, are also grouped as a subgenus, on account of their very flattened transverse section and the undulations of the suture of their chambers.

With regard to those Orthoceratites possessing a siphon composed of spheroidal elements of variable appearance, of which the principal types are *O. cochleatum*, Schlot., and *O. nummularium*, Sow., M. Barrande states that he has unsuccessfully attempted to assign to this class its proper place in that subdivision of Orthoceratites which possesses a siphon more or less straight and cylindrical. This difficulty is produced by the gradual transition between the nummuloid and the cylindrical formation of the elements of the siphon among the Orthoceratites; and it necessitates the distribution, of those of the Orthoceratites of Bohemia which are connected with the type of forms called *Cochleati*, among the different groups, according to the appearance of their ornamentation.

Classification of the Orthoceratites of Bohemia.

	Sections.	Categories.	Groups.	
Genus *Orthoceras.*	I. Short-coned Orthoceratites.	Transverse ornaments.	1	Horizontal or transverse striæ, more or less regular.
	II. Long-coned Orthoceratites.	*Provisional groups.* *Shell unknown.*	2	Contour of transverse section triangular. *O. triangulare.*
			3	Transverse section circular or elliptical.
		Longitudinal ornaments predominating.	4	Longitudinal ornamentation as ridges, furrows, edges, bands, striæ, or lines. *O. Doricum*, Barr., *O. Bacchus*, Barr., *O. spectandum*, Barr., *O. originale*, Barr., *O. Woodwardi*, Barr.

	Sections.	Categories.	Groups.	
Genus *Orthoceras*, Breyn.	II. Long-coned Orthoceratites (*continued*).	Mixed ornamentation.	5	Lines and striæ upon the whole of the length, with rings towards the point or middle region. *O. Bronni*, Barr., *O. electrum*, Barr., *O. Neptuni*, Barr.
			6	Lines and striæ upon the whole of the length, with rings over the whole surface. *O. patronus*, Barr., *O. pulchrum*, Barr., *O. pseudocalamiteum*, Barr., *O. solitarium*, Barr.
			7	Simple longitudinal lines, crossed by transverse lines of about equal intensity. *O. sericatum*, Barr., *O. loricatum*, Barr., *O. mimus*, Barr., *O. contextum*, Barr.
			8	Variable species in which sometimes the longitudinal and sometimes the transverse ornamentation predominates. *O. araneosum*, Barr., *O. victima*, Barr., *O. mutabile*, Barr.
		Transverse ornaments predominating.	9	Rings upon some part of the surface, accompanied only by rectilinear or sinuous transverse striæ. *O. dulce*, Barr., *O. annulatum*, Sow., *O. Agassizi*, Barr., *O. nobile*, Barr., *O. lunaticum*, Barr., *O. Nereidum*, Barr., *O. rigescens*, Barr.
			10	Transverse bands upon the surface, with superficial undulations, flattened rings, and deep grooves. *O. pedum*, Barr., *O. rivale*, Barr., *O. fasciolatum*, Barr., *O. aphragma*, Barr., *O. zonatum*, Barr.
			11	Transverse striæ, which are distinguished by transverse imbrication. *O. pleurotomum*, Barr., *O. placidum*, Barr., *O. Janus*, Barr., *O. Giebeli*, Barr.
			12	Transverse striæ, showing direct imbrication. *O. Simoïs*, Barr., *O. Lychas*, Barr., *O. timidum*, Barr., *O. asparagus*, Barr.
			13	Transverse striæ, without sensible imbrication. *O. capax*, Barr., *O. Minos*, Barr., *O. Hœrnesi*, Barr., *O. valens*, Barr.
			14	Species with a lamellose shell, which are not included, by reason of their more decided characters, in other groups. *O. severum*, Barr., *O. squamatulum*, Barr., *O. vulpes*, Barr., *O. Richteri*, Barr.
			15	Well-marked transverse striæ, without pronounced imbrication, but with very fine longitudinal striæ in the spaces between the transverse striæ. *O. senile*, Barr., *O. passer*, Barr., *O. Eichwaldi*, Barr., *O. Halli*, Barr.
			16	Little perforations of the shell, which co-exist with both transverse and longitudinal striæ. *O. porites*, Barr., *O. venustulum*, Barr., *O. Saturni*, Barr., *O. subtile*, Barr.
		Smooth shell, or slightly striated across.	17	Smooth shell, with occasional traces of transverse striæ. *O. aperiens*, Barr., *O. Tritonum*, Barr., *O. Arion*, Barr., *O. decipiens*, Barr.

Subgenus *Huronia* (Group 18).—Although our knowledge of these fossils is somewhat limited, it is sufficient to indicate that the shells of which they formed a part were "long-coned," and that in the great development of their siphons they offer a remarkable connexion, on the one hand with *Endoceras*, and on the other hand with the Orthoceratites having a large nummuloid siphon, called *Cochleati*. All the *Huroniæ* show a common and well-marked character, which consists in each of their elements being composed of two very distinct parts, viz.:—

1. Towards the base there exists a straight and cylindrical part which adjusts itself in the aperture of the element placed immediately below. This part, considered by itself, represents very well an element of the siphon of an *Endoceras*, such as *O. duplex*, or its analogous form *O. peregrinum*.

2. Higher up there is always a part more swollen (that is to say, having a larger diameter), of which the rounded profile is comparable to the ring of an Orthoceratite, adjusted upon the rectilinear and lower part of the same element. This upper portion, isolated, represents an element of a nummuloid siphon, like that of *O. cochleatum*, Schlot., or that of *O. nummularium*, Sow.

Subgenus *Endoceras*, Hall.—In this subgenus are comprised all those Orthoceratites with a large cylindrical siphon which characterize the first phases of the second Silurian fauna upon the two Continents, and which have been designated in the north of Europe *Vaginati*, and in America *Endoceras*. The species of this subgenus seemed for some time to possess a second characteristic in the marginal position of their large siphon. But the discoveries by Prof. J. Hall of *E. proteiforme*, with a large siphon, placed at a distance from the side of the shell, and by M. Eichwald of a Russian species, *E. hasta*, with a large central siphon, besides the discovery of a representative in Bohemia (*O. novator*), prove the inconstancy of this organ in these fossils.

Endoceras (Group 19).—Characterized by the great dimensions and cylindrical form of the siphon. This group is provisional, as the external appearance of the shell is not known. *O. peregrinum*, Barr., *O. novator*, Barr., *O. insulare*, Barr., *O. duplex*, Wahl.

Endoceras (Group 20).—The common character of this group consists in the very pronounced rings upon the external surface. Upon the European forms these rings are accompanied by striæ which follow the same direction. The three types belonging to the great northern zone are *O. vaginatum*, Schlot., *O. trochlearis*, His., *Endoceras annulatum*, Hall, while *O. Marcoui*, Barr., has been discovered by M. Jules Marcou in the calcareous lenticles of the schists of Phillipsburgh, Canada, upon an horizon which appears to correspond to the origin of the second fauna.

Subgenus *Gonioceras*, Hall.—Up to the present time this group is represented by the single species figured and described by Prof. J. Hall in 1847, under the name of *Gonioceras anceps*. The two principal characters which distinguish this subgenus are (1) the very flattened conformation of the transverse section, of which the axes

are in the proportion of 1 to 4, or of 1 to 5, and (2) the curves which indicate the sutures of the chambers, and which present a remarkable analogy with those shown by the sutures of the chambers in certain Goniatites.

M. Barrande has not associated this American species with the Orthoceratites which compose Group 2, already described, the historic type of which is *O. triangulare*—because, although there exists between these different forms a certain analogy, they appear to be sufficiently distinguished by the following differences :—

(1) The triangular section of the Orthoceratites of Group 2 is nearly in the form of an equilateral triangle, with its three angles slightly unequal; but in *G. anceps* the section shows a very flattened triangle, of which the lateral angles are very sharp, and very different from the angle at the summit.

(2) The undulations of the suture of the chambers are very pronounced in *G. anceps*. On the contrary nearly all the forms of Group 2 show a simple suture.

(3) All the species of Group 2 are characterized by the presence of an organic deposit, which fills up their siphon, in the form of radiating lamellæ. Upon the specimens of *Gonioceras* yet observed no trace of a similar deposit has been discovered. Besides these differences founded upon the characters of the forms, there exists a remarkable contrast with regard to the period of their appearance. The species which belong to Group 2 existed during the last phase of the Third Silurian fauna in Bohemia, and elsewhere in the Devonian fauna. On the contrary, *G. anceps* belongs exclusively to the limestone of the Black-River group, which is equivalent to the middle of the horizon occupied by the second fauna in America, and the part where this fauna did not acquire its full development.   [A. S.]

The FOSSIL MOLLUSCA *of the* TERTIARY BASIN *of* VIENNA. Vol. II. BIVALVES. Nos. 17 & 18. By Dr. MORITZ HÖRNES.

[Die fossile Mollusken des Tertiärbeckens von Wien. Von Der Moritz Hörnes. Band II. Bivalven. Lief. 17 & 18. Proc. Imp. Geol. Inst. Vienna. Dec. 3rd, 1867.]

THE Mytilaceæ are represented in the Vienna basin by 9 species of *Modiola*, 1 species of *Lithodomus*, 5 species of *Mytilus*, 3 species of *Congeria*, and two species of *Pinna*.

Of *Modiola* some species are found in the marls and sands of the Leithakalk, while others (*e. g. M. marginata, M. Volhynica*, Eichw., and *M. Letochæ*, Hörnes) occur exclusively in the Sarmatic beds.

The only species of *Lithodomus* which has been properly determined is *L. Avitensis*, Mayer; but some small nuclei from the Leithakalk may belong to *L. subcordatus*, D'Orb.

Among the *Mytili*, *M. Haidingeri* is remarkable for its abundance in certain strata, and for its peculiar ornamentation. Near Gauderndorf it is associated with a species the brown epidermis of which is constantly preserved. This has been regarded as a young form of *M. Haidingeri*, but is determined by the author to be a distinct species—*M. fuscus*. *M. oblitus*, Mich., and *M. superbus*, Hörn., are remarkable for the elegance of their ornamentation.

The *Congeriæ* are among the most characteristic forms of the uppermost beds of the Tertiary basins of Vienna and Hungary, these being generally known amongst Austrian geologists as "Congerian strata." The most important species in the neighbourhood of Vienna is *C. subglobosa*, Partsch; but it seems to be confined to that district. It is met with in immense numbers in a yellow loam and the underlying blue sandy clay (oberer Tegel), associated with *Melanopsis Martiniana*, Fér., *M. Bouei*, Fér., *Planorbis marginatus*, Drap., *Cardium apertum*, Münst., *Cardium conjungens*, Partsch, *Unio atavus*, Partsch, and several other species of brackish-water habits. These strata are peculiar to the Viennese and Hungarian basins; and *C. subglobosa*, though extremely abundant in certain localities, is very rare north of the Danube, being apparently represented by other species of the same genus.

Congeria triangularis occurs in the same division of the Vienna Tertiaries as the last species, but is never associated with it, being restricted chiefly to Moravia and Hungary. *C. rhomboidea* is a new species, occurring only at a few localities near Fünfkirchen, in Hungary. *C. Partschii*, Czjzek, is confined to a few localities near Vienna and in the Hungarian basin, but is never associated with *C. subglobosa*. *C. Czjzekii*, Hörn., is another rare species; it occurs only in the neighbourhood of Oedenburg (W. Hungary), associated with *C. triangularis*. Of the other species, *C. spatulata*, Partsch, is very abundant, and is found with *C. subglobosa*, generally inside it, while *C. amygdaloides* and *C. Basteroti* occur in marine deposits, the last-named being common to the Tertiary basins of Vienna, Bordeaux, and Touraine.

The genus *Pinna* has yielded two very large species, which occur also in the Subapennine deposits; they are *P. Brocchii*, D'Orb., and *P. tetragona*, Brocchi, and are found in the Leithakalk and the underlying marls.

The Malleaceæ are represented by 1 species of *Avicula* and 3 of *Perna*. The former is *A. phalænacea*, and occurs in the deposits of Grund and Gauderndorf, as well as in the Tertiary basins of Bordeaux and Touraine. *Perna Soldanii*, a gigantic species of tropical character, occurs also in the Subapennine deposits, as well as near Asti, and most abundantly at the mouth of the Rhone. *P. Rollei* and *P. radiata* are new species.

The Pectinidæ occurring in the Vienna basin are 5 species of *Lima*, 1 species of *Limea*, 19 species of *Pecten*, 1 species of *Hinnites*, 2 species of *Plicatula*, and 1 species of *Spondylus*.

The species of *Lima* are generally found in the sands of Grund, and closely resemble those of Touraine. One of them, *L. squamosa*, Lam., is a recent species, which ranges from the Mediterranean to the Atlantic coasts.

The only known species of *Limea*, *L. strigillata*, Brocchi, occurs in the Leithakalk and the Baden "Tegel," under the same circumstances as in other localities.

The species of *Pecten* have been of great assistance in fixing certain stratigraphical horizons in the Vienna basin. The most ancient species is *P. Holgeri*, Geinitz, which occurs in a coarse sand resulting

from the decomposition of granite, and resting on that rock. The same stratum is also characterized by *P. solarium*, Lam., which constitutes whole layers near Wiedendorf, in the environs of Krems. The deposits of this locality are connected with those of Ortenburg and Vilshofen (Bavaria), westward with those of Anjou and Touraine, and eastward with those of Hungary and Asia Minor as far as the plateau of Erzeroum. *P. solarium* is peculiar to the extra-alpine portions of the Vienna basin, and characterizes a determinate horizon in association with *Cardium Kubecki*, Hauer, and *Pectunculus Fichteli*, Desh. *P. Burdigalensis* (occurring only in the Hungarian basin, near Promontor on the Danube) and *P. palmatus*, Lam., from Gaudendorf, Eggenburg, Promontor, &c., also belong to the same horizon. *P. Beudanti*, Bast., and *P. Rollei*, Hörn., characterize a somewhat higher series, and are extremely abundant in the Echinus-beds of Gaudendorf. *P. aduncus*, Eichw., is highly characteristic of the true Leithakalk and its sands ; it abounds especially north-west of Vienna, and is associated with *P. Tournali*, Serres. Another characteristic species of the Leithakalk is *P. latissimus*, Brocchi, which is stated to occur in 27 localities in the Vienna basin. *P. Besseri*, Andr., and *P. Leithajanus*, Partsch, from the same deposit, have a wide extension. The Leithakalk and its equivalents range, from west to east, from Perpignan to Asia Minor, and, north to south, from Malta and the Morea to Upper Silesia. Probably they exist also in Italy, as the fossils from Siena and Monte Mario, near Rome, evidently correspond with species from the Vienna basin.

Pecten Reussii, Hörnes, is similar in sculpture to *P. Islandicus*, but cannot be identified with it or any other living species. *P. substriatus*, D'Orb., which has been frequently identified with *P. varius* or *P. pusio*, is regarded by the author as referable to a species represented in the older Tertiaries of Antwerp, Touraine, and Turin, and certainly not to *P. pusio*.

Pecten Malvinæ, Dubois, which was formerly referred to *P. opercularis*, and *P. elegans*, Andr. (*P. Sarmenticus*, Goldf.), are also abundant in the Leithakalk.

Pecten septem-radiatus, Müll., *P. cristatus*, Bronn, *P. duodecim-lamellatus*, Bronn, and *P. spinulosus*, Münst., are either confined to the Lower or Baden " Tegel," or are most abundant in that deposit. The first-named species exists in the Mediterranean at the present day ; the next two are extinct, but abound in the Italian Subapennine deposits ; and the last, found rarely at Saubriques, near Dax, and near Turin, is otherwise peculiar to the Vienna basin.

The genus *Hinnites* is represented only by some young specimens of *H. Defrancei*, Micht.

Two species of *Plicatula* (*P. mytilina*, Phil., and *P. ruperella*, Duj.) are met with in great abundance, especially in the marl-beds beneath the Leithakalk.

Of the *Spondyli*, *S. crassicosta*, Lam., is a characteristic species of the Lower Neogene deposits of Europe, and especially of the Leithakalk of the Vienna basin. *S. gaderopus*, L., is a recent species abundant in the Mediterranean ; and *S. Miocænicus*, Micht., occurs at Lapugy, in Transylvania.   [Count M.]

On VITREOUS *and* SEMIVITREOUS ROCKS. By Dr. F. ZIRKEL.

THE rocks submitted to microscopic investigation by the author came from the Trachytic regions of Hungary, the Euganeans, Iceland, St. Paul, and New Zealand, with some porphyries from Saxony. The specimens exhibiting devitrification show distinct traces of the passage of the rocks from the liquid to the solid state, thus affording decisive proof that since their solidification no change has taken place in the relative situations of even the minutest crystalline constituents. They also contain minute tabular crystals of magnetic iron-ore, prisms of augite or hornblende, and felspar in microscopic crystals. Although sanidine is the most abundant of the felspathic constituents of vitreous rocks, triclinic felspar is of frequent occurrence either in isolated crystals or associated with sanidine, and is of much more general occurrence than is usually supposed. Both felspars frequently include either vitreous or partially devitrified substances in accordance with those which surround them, thus proving that the crystals of felspar have crystallized out of the amorphous paste which the rock originally consisted of. The vitreous substance frequently penetrates into the interior of the crystals in the form of ramifications. This is the case, also, with the quartz which sometimes occurs in certain varieties of pitchstone.

Of the vitreous rocks obsidian is the most typical, although the process of devitrification has commenced in it, as is exhibited in its most advanced stage in pumice. In the latter the formation of pores has reached its maximum; but such cavities exist also in obsidian, though they have not yet been found to contain liquid substances. The vitreous granules of perlite have been found to include belonite and trichite; but the crystalline results of devitrification are quite different from the concentric structure exhibited by the granules of perlite. The same may be said of the granules of spherulite and the felspar and magnesian mica crystallized out of them.

The trachytic porphyries generally present traces of progressive devitrification. In the Iceland rocks sanidine is most abundant; but the existence of triclinic felspar has been carefully ascertained, and its crystals have been found to contain numerous pores, generally filled with gaseous substances, but sometimes with crystals of quartz.

A variety of pitchstone from the Island of Arran presents a good instance of vitrified and devitrified substances in crystals of quartz having uniformly an hexagonal form.

The older pitchstone (euritic pitchstone) is composed of a vitreous substance with simple refraction, and of a double-refracting euritic material, with scarcely any admixture of belonite, but interspersed with sanidine (including vitreous material), triclinic felspar, quartz (with numerous pores containing liquids), and black mica. The formation of eurite must consequently have taken place at the moment of solidification, and cannot be ascribed to a subsequent metamorphosis. The connexion between pitchstone and euritic porphyry, which has long been admitted on geological grounds, is thus confirmed by the microscopic investigation of the specimens described by Dr. Zirkel, which were obtained from the district near Meissen, Saxony. [COUNT M.]

ALPHABETICAL INDEX.

TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described, and those of which the names are printed in italics are also figured.]

THE END.

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