# LONDON GEOLOGICAL SOCIETY

## QUARTERLY JOURNAL

15

1859

# GEOLOGICAL SOCIETY OF LONDON.

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*ANNUAL GENERAL MEETING, FEB.* 18, 1859.

## REPORT OF THE COUNCIL.

The Council of the Geological Society, in presenting their Annual Report to the Members, have pleasure in referring to the undiminished prosperity of the Society. They have, however, to regret that the number of deaths recorded in 1858 has been beyond precedent, having amounted (including several which occurred in former years, but were only recently ascertained) to forty, which, with eleven resignations and the removal of four defaulters, makes a reduction of fifty-five. An unusually large number of new Fellows (forty-one) have been elected, and nine who had before been elected, have paid their admission-fees, making an addition of fifty ordinary Fellows.

Two foreign Members have been elected to fill two places vacated; the one by death, the other by admission to ordinary Fellowship.

The total number of the Society at the close of 1857 was 877; at the close of last year, 872.

The Council have to report that the income of the year has exceeded the expenditure by £28 5*s.* 5*d.*; and that in this expenditure is included the sum of £55 15*s.* 11*d.*, the cost of printing Mr. Ormerod's Classified Index to the Publications of the Society, which, being now complete, will, it is hoped, at once be applied for by those Members who are desirous of acquiring so useful a book of reference.

The amount of the Funded Property of the Society remains the same, viz. £4578 19*s.* 2*d.*, including £500, the legacy of the late Mr. Greenough, of which about £55 has been disbursed in charges incidental to his bequest of books and maps, and temporarily liquidated out of the ordinary expenditure of the last three years.

Amongst other donations received since the last Anniversary, the

Council have to make special mention of a marble bust of the late Dr. M'Culloch, bequeathed to the Society by his widow; and of the munificent gift, by Professor Agassiz, of the whole of his unpublished drawings of Fossil Fishes.

The 14th volume of the Quarterly Journal has been completed, and the first part of the 15th volume published.

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

The Council have to announce that active progress is making, by a special Committee, in preparing a new edition of Mr. Greenough's Geological Map, two sheets of which, including Wales and the south-west of England, may, it is hoped, be ready for publication about the time of the Anniversary.

A special Committee was also appointed to direct the expenditure of the grant of £100, made by the Royal Society for the purpose of a systematic excavation of the Bone-cave at Brixham. That sum being nearly exhausted, the Committee have made application for and received an additional grant from the Royal Society.

The Council, concurring in the views of the previous Council as to the value of the juxtaposition of the Societies, have made renewed efforts, by application to Government, to obtain accommodation at Burlington House as soon as additional buildings shall be erected on that site.

The Council have carefully considered the basis of a new arrangement to be proposed to the Society with respect to the Admission-fees and Subscriptions of Fellows to be elected in future; and will submit the particulars of their plan, in accordance with the Statutes, to a Special General Meeting of the Society, to be called shortly after the Anniversary.

They have in the meanwhile ordered that the Quarterly Journal shall be circulated *gratis* among all the Compounders and Resident Contributing Fellows, commencing with the February Number.

In consequence of representations that greater convenience would thereby be obtained, the Council have ordered that the Annual Dinner should not, as a matter of course, take place on the Anniversary, and have fixed it for this year on the day following.

A special Museum Committee has been appointed for the purpose of improving the arrangement and condition of the various collections belonging to the Society, and making them more available for the reference and study of the Members.

In conclusion, the Council have to state that they have awarded the Wollaston Medal to Charles Darwin, Esq., F.R.S., F.G.S., for his numerous contributions to Geological Science, more especially his observations on the Geology of South America, on the Phænomena of Volcanic Islands, on the structure and distribution of Coral-reefs, and his Monographs on recent and fossil Cirripedia; and the proceeds of the Wollaston Donation Fund to Mr. Charles Peach, of Wick, N.B., for his meritorious exertions in the collection of rare organic remains, and particularly for having led the way in the discovery of Silurian Fossils in the hard and subcrystalline rocks of the southern headlands of Cornwall and of the north-western extremity of Scotland.

*Report of the Library and Museum Committee.*

*Library.*

The greater part of the surplus volumes and pamphlets belonging to the Greenough Bequest, which remained after the distribution last year, have been sent to the Library of the Geological Survey of India, at Calcutta, in accordance with a resolution to that effect.

The increased number of books, and more especially of periodical publications (the latter now in great part consisting of a long series of volumes), has rendered necessary their being re-arranged on the shelves. At present, portions of the most important periodicals are placed on separate shelves, and even in different rooms,—a condition of things which must be remedied as soon as possible, but which can only be done with much care and labour.

A list, printed in alphabetical form, is now highly desirable, of the books and maps which have been received since 1854; including those bequeathed by the late G. B. Greenough, Esq. Your Committee respectfully recommend that this be done at an early convenience.

The valuable Index, prepared by Mr. Ormerod, was printed and published in the course of last autumn. Fifty copies have been sold; but more than one hundred gentlemen entered their names as subscribers, many of whom, however, have not as yet demanded their copies.

Your Committee beg to suggest a revision of the List of British and Foreign Institutions receiving grants of the Quarterly Journal.

The many Maps received in 1858–9 have been mounted, when they required it, and are arranged in appropriate cases. Amongst the Maps lately added to the Library, we may mention particularly Mylne's Geological and Topographical Map of London, some sheets of Von Dechen's Geological Map of Rhenish Prussia, some sheets of the Survey of Portugal, the Maps published by the Middle Rhine Geological Society, and Col. Jervis's Geological Map of the Crimea.

We notice with much pleasure a new and important class of donations to our Library,—that of photographs (stereoscopic and ordinary) of Geological scenery, and of fossils. We refer to those of the Basalt, in the Walsall Quarries, presented by Mr. Twamley; of Purbeck and Portland, presented by Mr. Thompson, of Weymouth; of the Nototherium from Australia; and of some Fossil Fish-teeth from Nova Scotia.

*Museum.*

The numerous donations of rock-specimens, minerals, and organic remains which have been received during the past year, and particularly from abroad, admit, for the most part, of convenient disposition upon our shelves; some, however, must for the present be placed aside for want of room.

The examination and description of our valuable collection of fossil plants, of secondary age, from Nagpur, has been undertaken by Charles Bunbury, Esq., F.G.S.

The arrangement of rock-specimens, commenced by Mr. Pratt, is now being continued by Mr. Horner.

The drawers in the Museum and in the Cabinet of Minerals have been re-papered to a considerable extent. The specimens have been for the most part cleansed, and, where necessary, re-fastened to their tablets.

Many specimens, large and small, including elephant's teeth, &c., have been repaired or set in plaster. Of some, possessing sufficient interest, casts have been made, in plaster or gutta-percha.

The Assistant-Secretary has received much aid from Mr. John Wetherell during the past year, in the Museum, in the work above mentioned, and in waiting upon visitors. Mr. Wetherell has also been very useful in indexing and arranging books, in copying papers, and in other labours in the Library. Besides being very attentive to his general duties, he has executed several good diagrams for the Evening Meetings. As Mr. Wetherell is about to resign his situation among us, on account of his private affairs, the early appointment of a competent successor becomes urgent.

The Special Committee appointed for the re-formation of the Museum have commenced their labours, and will report every three months, according to the directions they received.

John Carrick Moore.
John J. Bigsby.
Warington W. Smyth.

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*Comparative Statement of the Number of the Society at the close of the years* 1857 *and* 1858.

| | Dec. 31, 1857. | | Dec. 31, 1858. | |
|---|---|---|---|---|
| Compounders | | 126 | | 121 |
| Residents | | 188 | | 192 |
| Non-residents | | 497 | | 493 |
| | | 811 | | 806 |
| Honorary Members | 12 | | 12 | |
| Foreign Members | 50 | | 50 | |
| Personages of Royal Blood | 4— | 66 | 4— | 66 |
| | | 877 | | 872 |

*General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years* 1857 *and* 1858.

| | | | |
|---|---|---|---|
| Number of Compounders, Residents, and Non-residents, December 31st, 1857 | | | 811 |
| *Add* Fellows elected during former years, and paid in 1858 | Residents .. 2; Non-residents 7 | — 9 | |
| Fellows elected and paid during 1858 | Residents .. 9; Non-residents 32 | —41 | |
| | | — | 50 |
| | | | 861 |
| *Deduct* Compounders deceased | | 6 | |
| Residents ,, | | 3 | |
| Non-residents ,, | | 31 | |
| Resigned (3 Res., 8 Non-Res.) | | 11 | |
| Removed (Res.) | | 4 | |
| | | — | 55 |
| Total number of Fellows, Dec. 31st, 1858, as above | | | 806 |
| Number of Honorary Members, Foreign Members, and Personages of Royal Blood, Dec. 31st, 1857 | | | 66 |
| *Add* Foreign Members elected during 1858 | | | 2 |
| | | | 68 |
| *Deduct* Foreign Member deceased | | 1 | |
| Foreign Member resigned (having become an Ordinary Fellow) | | 1 | |
| | | — | 2 |
| | As above | .... | 66 |

*Number of Fellows liable to Annual Contribution at the close of* 1858, *with the alterations during the year.*

| | | |
|---|---|---|
| Number at the close of 1857 | | 188 |
| *Add* Elected in former years, and paid in 1858 | | 2 |
| Elected and paid in 1858 | | 9 |
| Non-residents who became Resident | | 11 |
| | | 210 |
| *Deduct* Deceased | 3 | |
| Resigned | 3 | |
| Removed | 4 | |
| Compounded | 1 | |
| Became Non-resident | 7 | |
| | — | 18 |
| As above | | 192 |

## Deceased Fellows.

### *Compounders* (6).

Sir C. M. Clarke.
William Palmer, Esq.
Henry Perkins, Esq.
Rev. E. Tagart.
Richard Taylor, Esq.
Henry Warburton, Esq.

### *Residents* (3).

The Duke of Devonshire.
Lieut.-Colonel Sir W. Reid.
R. H. Solly, Esq.

### *Non-residents* (31).

Rev. J. W. Barnes.
Benjamin Best, Esq.
Thomas Bodley, Esq.
G. W. Braikenridge, Esq.
P. D. Cooke, Esq.
Sir W. G. Cumming.
The Dean of Ely.
J. M. Heath, Esq.
William Holbeck, Esq.
James Jardine, Esq.
Joshua King, Esq.
H. F. Mackworth, Esq.
Sir G. Magrath.
B. Moore, Esq.
John Murray, Esq.
G. T. Nicholson, Esq.
J. M. Paine, Esq.
H. L. Pattinson, Esq.
W. Peile, Esq.
Baden Powell, Esq.
Dr. Chas. Price.
R. T. Rickards, Esq.
Rev. P. Serle.
Rev. L. Sneyd.
James Thomson, Esq.
T. S. Thomson, Esq.
T. J. Torrie, Esq.
R. E. Townsend, Esq.
Joseph Wickenden, Esq.
Capt. S. Widdrington.
Hon. and Rev. Robert Wilson.

### *Foreign Member* (1).

Professor Weiss.

*The following Persons were elected Fellows during the year* 1858.

January 6th.—Timothy Curley, Esq., Hereford; and Rev. A. W. Ingram, M.A., Hawington.

—— 20th.—William Adams, Esq., Ebbw Vale; and Rev. F. H. Morgan, M.A., Hemel Hempstead.

February 3rd.—Rev. Frederick Smithe, M.A., Church Deen, Gloucestershire; Rev. Wm. A. Jones, M.A., Taunton; and Viscount Dufferin, Highgate.

—— 24th.—T. A. Sanford, Esq., Nynehead Court, Wellington; C. E. Austin, Esq., Croydon; and R. H. Polwhele, Esq., Geological Survey of Great Britain.

March 10th.—Alfred Williams, Esq., Newport, Monmouthshire.

—— 24th.—Henry Becket, Esq., Wolverhampton; Wm. Fletcher, Esq., Tarn Bank, Cockermouth; J. R. Burnell, Esq., Lincoln's Inn Fields; G. H. Morton, Esq., Liverpool; G. C. Greenwell, Esq., Radstock; Samuel Dobson, Esq., Treforest; Elkanah Billings, Esq., Montreal; and J. J. Forrester, Esq., Oporto.

April 28th.—H. D. M. Spence, Esq., Hyde Park Square; Parkin Jeffcock, Esq., Derby; James Powrie, Esq., Reswallie; and Marcus Huish, Esq., Derby.

May 12th.—Walter Jauncey, Esq., Birmingham; and Edmund Cavill, Esq., Saxmundham.

—— 26th.—Henry Duckworth, Esq., Liverpool; David C. McConnell, Esq., Tooting; Frederick Drew, Esq., Geological Survey of Great Britain; and John Entwisle, Esq., Russell Square.

June 9th.—John Millar, Esq., Bethnal Green; W. H. Le Feuvre, Esq., Jersey; Thomas Evans, Esq., Cardiff; W. S. Clark, Esq., Aberdare; Major E. R. Wood, Stout Hall, Glamorganshire; and Charles Falconer, Esq., Sackville Street.

—— 23rd.—Handell Cossham, Esq., Mangotsfield, Bristol.

November 3rd.—Rev. A. S. Farrar, M.A., Queen's College, Oxford.

—— 17th.—Augustus Smith, Esq., M.P., Eaton Square.

December 1st.—George Dixon, Esq., Whitehaven; J. D. Smythe, Esq., Madhopoor; Samuel Lang, Esq., Lymington; H. T. Plews, Esq., Bedale; Rev. John Anderson, Newburgh; J. A. Tulk, Esq., Whitehaven; James Clarke, Esq., Dalston; Right Hon. Lord Kinnaird, Rossie Priory, Scotland; Capt. H. H. Godwin-Austen, H.M. 21st Regiment; Major-General Emmett, R.E.; and W. B. D. Mantell, Esq., New Zealand.

—— 15th.—Henry Christy, Esq., Victoria Street; John Sharp, Esq., Tunbridge Wells; Joseph Paull, Esq., Aldstone; Rev. J. H. Austen, Ensbury; and Rev. Alexander Maclennan, Newington Butts.

*The following Persons were elected Foreign Members.*

March 10th.—Herr Arn. Escher von der Linth, Zurich; and Dr. J. A. Eudes Deslongchamps, Caen.

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

*British Specimens.*

A Series of Molten Specimens of the Rowley Basalt; presented by W. Hawkes, Esq.

Extraneous Fossils from the Crag; presented by S. V. Wood, Esq., F.G.S.

Coral from the Lower Greensand at Chilworth; presented by R. Godwin-Austen, Esq., F.G.S.

Nodules, &c., from the London Clay; presented by N. T. Wetherell, Esq.

Specimen of Acrodus Teeth from the Lias; presented by Lieut. Breton, F.G.S.

Specimens of Fossiliferous Ironstone from Lenham, Kent; presented by W. Harris, Esq., F.G.S.

Granite-veins from the Carbonaceous Rocks east of Dartmoor; presented by G. W. Ormerod, Esq., F.G.S.

Striated Boulders from Suffolk; presented by the Rev. J. Gunn, F.G.S.
Suite of Sutherland and Caithness Specimens; presented by Sir R. I. Murchison, V.P.G.S.

*Foreign Specimens.*

Rocks and Fossils from Turkey; presented by Capt. T. A. Spratt, R.N., F.G.S.
Specimens of Fossil Fishes from Siberia; presented by C. E. Austin, Esq., F.G.S.
Specimens of Lignite and Fossil Teeth, &c., from Agnani, Italy; presented by Capt. Montagna.
Cast of Illænus tauricornis; presented by His Excellency Prof. Kutorga.
Specimens of Rocks from Bahia; presented by H. G. Bowen, Esq., F.G.S.
Series of Fossils from North America; presented by M. J. Marcou.
Specimens of Rocks and Fossils from Asia Minor; presented by Major R. J. Garden.
Fossils from South Africa; presented by Dr. R. N. Rubidge.
Fossils from South Africa; presented by G. W. Stow, Esq.
Specimens from the Mineral Springs of Aske, Persia; and Metallic Ores, &c., from Tabriz: presented by the Hon. Chas. A. Murray.
Specimens of Minerals from Aden, Siam, and Sarawak; presented by R. Coulson, Esq.
Fish-teeth in Coal-shale from Nova Scotia; presented by Sir C. Lyell, F.G.S.
Specimens from Shark's Bay, Australia; presented by the Lords Commissioners of the Admiralty.
Specimens of Mastodon Teeth; presented by S. P. Pratt, Esq., F.G.S.
Head of a Trilobite from Uitenhage; presented by Dr. W. G. Atherstone.

Charts, Maps, &c.

41 Charts published by the Dépôt de la Marine; presented by the Director-General of the Dépôt de la Marine.
Dr. Von Dechen's Geologische Karte der Rhein-Provinz und der Provinz-Westfalen; presented by Sir R. I. Murchison, V.P.G.S.
Geological Map of the Estuary of the Thames, prepared by Joseph Prestwich; presented by the Author.
Mapa Topográfico de la Provincia de Oviedo trazado por D. G. Schulz, 1857; and Mapa Geológico (1857): presented by the Author.
Profile of Rocks crossing part of Massachusetts, by E. Hitchcock, 1823;
Geological Map of Wisconsin, by J. Lapham, 1855;
Map showing the route pursued by the Exploring Expedition to New Mexico and the Southern Rocky Mountains by H. Fremont, J. W. Abert, and W. G. Peck, 1845;

Delta of the Mississippi, by A. Talcott and T. J. Lee, 1839;

Topographical Map of the Road from Missouri to Oregon, by J. C. Fremont (in 7 sections), 1846;

Upper California, by Coulter, 1835;

Comparative Height of Mountains and Length of Lakes and Rivers (State of New York), by E. Emmons, 1842;

Map of that part of the Mineral Lands adjacent to Lake Superior ceded to the United States by the Treaty of 1842 with the Chippeways, by G. Talcott, A. B. Gray, and J. Leib, 1845; presented by Sir Chas. Lyell, F.G.S.

Geological and Topographical Map of London and its Environs, by R. W. Mylne, 1858; presented by the Author.

Plans of various Lakes and Rivers between Lake Huron and the River Ottawa; presented by Sir Wm. Logan, F.G.S.

Karte von dem Grossherzogthume Hessen (Section Offenbach), von G. Theobald und R. Ludwig, 1858; presented by the Darmstadt Geographical Society.

Geologische Kaart van Nederland vervaardigd door Dr. W. C. H. Staring, Blad 14; presented by the Author.

Plano Hydrographico da Barra do Porto de Lisboa, 1857; and Survey of Portugal, Sheets Nos. 19 & 23: presented by Gen. F. Folque.

A Relief-Map of Brighton and its Environs, by J. Brion and Sons; the Geology by E. P. Wilkins: presented by the Authors.

Carte Géologique des Couches crétacées du Limbourg en dessous des assises quaternaires et tertiaires, par J. J. T. B. v. d. Binkhorst; presented by the Author.

Carte des Etats-Unis de l'Amérique-nord pour servir aux Observations Géologiques, par Maclure (J. Marcou), 1857; presented by M. Marcou.

Geological Map of New Mexico, by M. Jules Marcou, 1857; presented by the Author.

Portrait of Jules Thurmann, and Portrait of Jean de Charpentier; presented by M. Jules Marcou.

5 Photographs of Fossil Teeth from Nova Scotia; presented by Sir Chas. Lyell, F.G.S.

Photographs of Zygomaturus; presented by His Excellency Sir W. Denison.

Tabular View of the Arrangement of British Rocks, by T. A. Readwin; presented by the Author.

Illustrations of the Geologic Scenery of Weymouth, Portland, and Purbeck, 2 parts by P. Brannon; presented by the Author.

4 Photographs of Columnar Basalt, near Walsall; presented by C. Twamley, Esq., F.G.S.

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Marble Bust of the late Dr. M'Culloch, with Pedestal. Bequeathed by the late Mrs. M'Culloch.

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

Abich, Dr. H., For.M.G.S.
Admiralty, Lords Commissioners of the.
Art-Union, London.
Asiatic Society of Bengal.
Athenæum Journal, Editor of the.
Atherstone, Dr. W. G.
Atlantis, Editor of the.
Austin, C. E., Esq., F.G.S.

Babbage, C., Esq.
Basel, Natural History Society of.
Bechi, Sign. E.
Berkley, J. J., Esq., F.G.S.
Berlin, German Geological Society at.
Berlin Royal Academy of Sciences.
Berwickshire Naturalists' Club.
Binkhorst, Herr J. J. van den.
Bloxham, Thos., Esq.
Bohn, H. G., Esq.
Bowen, H. G., Esq., F.G.S.
Brannon, P., Esq.
Breslau Academy.
Breton, Lieut., F.G.S.
Brion, J., Esq.
British Government.
Bronn, Prof. H. G., For.M.G.S.

Cambridge Philosophical Society.
Canadian Institute.
Canadian Journal, Editor of the.
Carter, H. J., Esq.
Catullo, Prof. T. A.
Chemical Society of London.
Cherbourg, Société Impériale des Sciences Naturelles de.
Colliery Guardian, Editor of the.
Comision encargada de formar el Mapa Geológico de la Provincia de Madrid.
Copenhagen, Royal Society of.
Coulson, R., Esq.
Council of Education.
Critic, Editor of the.

Dana, Prof. J. D., For.M.G.S.
D'Archiac, M. le Vicomte, For. M.G.S.
Darmstadt Geographical Society.
Daubrée, M.
Davidson, Thos., Esq., F.G.S.
Dawson, J. W., Esq., F.G.S.
Delesse, M. A.
Denison, His Excellency Sir W.
Deshayes, Prof. G. P., For.M.G.S.
Deslongchamps, Dr. J. A., For. M.G.S.
Dewalque, M. G.
Dublin Geological Society.

East India Company, The Hon.
Ebray, M. Th.
Egerton, Sir P. G., Bart., M.P., F.G.S.
Erdmann, Prof. A.

Favre, Prof. A.
Folque, Gen. F.
France, Geological Society of.
Francfort, Dr. E., F.G.S.
Francis, Dr.
Franklin Institute of Pennsylvania.

Garden, Major R. J.
Gaudin, M. C. T.
Gaudry, M. Albert.
Geinitz, Prof. H. B., For. M.G.S.
Gemmellaro, Sign. G. G.
Geological Survey of the United Kingdom.
Geologist, Editor of the.
Gibb, Dr. G. D., F.G.S.
Giebel, Prof. C.
Gioenia Accademia di Scienze Naturali.

Godwin-Austen, R., Esq., F.G.S.
Goeppert, Prof. H. R., For. M.G.S.
Gould, Dr. A.
Greg, R. P., Esq., F.G.S.
Gunn, Rev. J., F.G.S.

Hamilton, W. J., Esq., For. Sec. G.S.
Harlem, Société Hollandaise des Sciences.
Harris, Wm., Esq., F.G.S.
Hauer, Herr F. Ritter v.
Haughton, Rev. Prof. S., F.G.S.
Hausmann, Prof. J. F. L., For. M.G.S.
Hawkes, W., Esq.
Hébert, M. E.
Heer, Prof. O.
Heidelberg Natural History Society.
Helmersen, Col. G. von, For. M.G.S.
Hennessy, Prof. H.
Henwood, W. J., Esq., F.G.S.
Historic Society of Lancashire and Cheshire.
Holmes, Prof. F. S.
Horner, L., Esq., V.P.G.S.
Hörnes, Dr. M.

Indian Archipelago Journal, Editor of the.
Institute of Actuaries.
International Association for obtaining a Uniform Decimal System.

Jennings, F. M., Esq., F.G.S.
Jenyns, Rev. L., M.A., F.G.S.
Jones, T. Rupert, Esq., F.G.S.

King, Prof.
Koninck, Prof. L. de, M.D., For. M.G.S.
Kutorga, His Excellency Prof.

Lartêt, M. E., For. M.G.S.
Lea, Dr. I.
Le Hon, M. H.
Lettsom, W. G., Esq.
Liége, Société Royale des Sciences de.
Linnean Society.
Literary Gazette, Editor of the.
Liverpool Literary and Philosophical Society.
Logan, Sir W. G., F.G.S.
Lombardy Institute.
Lucas, Rev. S., F.G.S.
Lyell, Sir Charles, F.G.S.

M'Adam, J., Esq., F.G.S.
M'Culloch, Mrs.
Malahide, Lord Talbot de, F.G.S.
Mallet, R., Esq.
Malvern Natural History Club.
Manchester Literary Society.
Marcou, M. Jules.
Maury, Dr. M. F.
Mendicity Society.
Meyer, Herr Herman von, For. M.G.S.
Microscopical Society.
Mill, J. S., Esq.
Miller, J., Esq., F.G.S.
Mitchell, J., Esq., F.G.S.
Montagna, Sign.
Montreal Natural History Society.
Moscow Imperial Society of Naturalists.
Murchison, Sir R. I., V.P.G.S.
Murray, Hon. C. A.
Mylne, R. W., Esq., F.G.S.

Nardo, Dr. G. D.
Naumann, Dr. Carl F., For. M.G.S.
Normandy, Linnean Society of.

Oldham, T., Esq., F.G.S.
Oppel, Dr. A.
Ordnance Survey of Great Britain.
Ormerod, G. W., Esq., F.G.S.
Owen, Prof. R., F.G.S.

Palæontographical Society.

Paris, Academy of Sciences of.
Paris, Ecole des Mines de.
Paris, M. le Directeur-Général du Dépôt de la Marine de.
Paris, Muséum d'Histoire Naturelle de.
Philadelphia Academy of Natural Sciences.
Photographic Society.
Pictêt, Prof. F. J.
Podrecca, Dr. G. L.
Pomological Society.
Ponzi, Prof. G.
Pratt, S. P., Esq., F.G.S.
Prestwich, J., Esq., Treas. G.S.
Puy, Société du.

Reeve, L., Esq., F.G.S.
Rennie, G., Esq., F.G.S.
Rogers, E., Esq., F.G.S.
Rogers, Prof. W. B., For.M.G.S.
Roper, R. S., Esq., F.G.S.
Royal Academy of Belgium.
Royal Academy of Lisbon.
Royal Asiatic Society.
Royal Astronomical Society.
Royal College of Physicians.
Royal Cornwall Polytechnic Society.
Royal Dublin Society.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Irish Academy.
Royal Society of Edinburgh.
Royal Society of London.
Royal University of Christiania.
Rubidge, Dr. R. N.

Sandberger, Dr. Fridolin.
Scarborough Philosophical and Archæological Society.
Schmidt, Herr J. F. J.
Scrope, G. P., Esq., M.P., F.G.S.
Senckenberg Natural History Society.
Silliman, Prof., M.D., For.M.G.S.
Smyth, R. Brough, Esq., F.G.S.
Society of Arts.
Somersetshire Archæological and Natural History Society.
Spratt, Capt. T. A., R.N., F.G.S.
Staring, Dr.
Statistical Society.
Stockholm Royal Academy of Sciences.
Storer, Dr. D.
Stow, G. W., Esq.
St. Petersburg Academy of Sciences.
Strickland, Mrs. H.
Surrey Archæological Society.

Tate, G., Esq., F.G.S.
Taylor, A., Esq.
Taylor, R., Esq., F.G.S.
Tchihatcheff, M. P. de.
Tennant, Prof. J., F.G.S.
Turin Royal Academy of Sciences.
Twamley, C., Esq., F.G.S.
Tylor, A., Esq., F.G.S.
Tyndall, Prof.
Tyneside Naturalists' Field Club.

University College.

Vaudoise Society of Natural Sciences.
Vienna Geological Institute.
Vienna Imperial Academy of Sciences.
Villa, Sig. G. B.

Wetherell, N. T., Esq.
Wetterau Society.
Wiesbaden, Natural History Society of.
Wilkins, E. P., Esq., F.G.S.
Wood, Ed., Esq., F.G.S.
Wood, S. V., Esq., F.G.S.
Wurtemburg Natural History Society.

Zepharovich, Herr V. Ritter, von.
Zigno, M. Achille de.
Zoological Society.

*List of* PAPERS *read since the last Anniversary Meeting, February* 19*th*, 1858.

1858.

Feb. 24th.—On the Gradual Elevation of a part of the Coast of Sicily, by Sign. G. G. Gemmellaro; communicated by Sir C. Lyell, F.G.S.

———— On the Occurrence of Chalk-flints and Sea-shells in a Peat-moss at Abernethy, N.B., by K. Maknab, Esq. (In a letter to the Secretaries.)

———— On the Occurrence of Striated Stones and Sea-shells at high levels in Scotland, by J. F. Jamieson, Esq.; communicated by Sir R. I. Murchison, V.P.G.S.

———— On the Changes of Level in the country near Tenby, by R. Mason, Esq. (In a letter to the Secretaries.)

March 10th.—Notes on the Gold-diggings of Creswick Creek and Ballaarat, by Mr. Redaway; communicated by Sir R. I. Murchison, V.P.G.S.

———— Notes on the Gold-field of Ballaarat, by Mr. J. Phillips; communicated by Sir R. I. Murchison, V.P.G.S.

———— On the Geology of the Gold-fields of Victoria, by A. R. Selwyn, Esq.; communicated by Prof. A. Ramsay, F.G.S.

———— On the Zygomaturus trilobus of Macleay, from Australia, by Prof. R. Owen, F.G.S.

March 24th.—On a protrusion of Silurian Rock in the North of Ayrshire, by J. C. Moore, Esq., F.G.S.

———— On the Rock-basins of Dartmoor, by G. W. Ormerod, Esq., F.G.S.

———— On the Kelloway Rock of the Yorkshire Coast, by J. Leckenby, Esq.; communicated by J. Morris, F.G.S.

April 14th.—On Nodules in the Crag, containing the Graphularia of the London Clay, by N. T. Wetherell, Esq.; communicated by the President.

———— On the Extraneous Fossils of the Crag, by S. V. Wood, Esq., F.G.S.

———— On a Fossil Fruit from Swanage Bay, by Prof. John Phillips, Pres. G.S.

April 28th.—On some Fossil Leaves from Madeira, by C. J. F. Bunbury, Esq., F.G.S.

———— On the Structure of Stigmaria ficoides, by E. W. Binney, Esq., F.G.S.

———— On the Lower Coal-measures of British America, by Prof. J. W. Dawson, F.G.S.

———— On some Sections of the Scottish Coal-measures, by Rev. T. Brown; communicated by Sir R. I. Murchison, V.P.G.S.

———— On a species of Fern from the Coal-measures of Worcestershire, by Prof. John Morris, F.G.S.

May 12th.—On the Glacial Conditions of Canada during the Drift-period, by Prof. Ramsay, F.G.S.

May 12th.—On the Lamination of some Rocks, by G. P. Scrope, Esq., M.P., F.G.S.

May 26th.—On the Westward Extension of the Raised Beach of Brighton, by Joseph Prestwich, Esq., Treas. G.S.

——— On the Sedimentary Relations of the Palæozoic Strata of New York, by J. J. Bigsby, M.D., V.P.G.S.

June 9th.—On the Jointings and Dolomites near Cork, by Prof. Harkness, F.G.S.

——— Results of some Experiments on the Melting and Cooling of Rowley Rag, by W. Hawkes, Esq.; communicated by the President.

——— On the Iron-ores of Exmoor, by W. W. Smyth, Esq., F.G.S.

——— On some Native Copper from Llandudno Mine, by W. Vivian, Esq.; communicated by John Taylor, Esq., F.G.S.

——— On the Slates and Trap-rocks of Easdale and Oban, by Prof. J. Nicol, F.G.S.

June 23rd.—On some Points in the History and Formation of Etna, by Dr. H. Abich, F.M.G.S. (In a letter to Sir C. Lyell, F.G.S.)

——— On the Lacustrine or Karéwah Deposits of Kashmere, by Capt. H. H. Godwin-Austen; communicated by R. Godwin-Austen, Esq., F.G.S.

——— On the Black Mica of the Granite of Leinster and Donegal, by Rev. Prof. S. Haughton, F.G.S.

——— On an Outlier of Lias in Banffshire, by T. F. Jamieson, Esq. (In a letter to Sir R. I. Murchison, V.P.G.S.)

——— Notes on a Collection of Australian Fossils in the Museum of the Natural History Society of Worcester, by Prof. Owen, F.G.S.

——— On the Occurrence of some Tertiary Fossils at Grove Ferry near Canterbury, by John Brown, Esq., F.G.S.; with notes on the new species by G. B. Sowerby, Esq.

——— On the Fossil Crustacean found by Mr. Kirkby in the Magnesian Limestone of Durham, and on a new species of Amphipod, by C. Spence Bate, Esq.; communicated by Dr. Falconer, F.G.S.

——— On Eurypterus, by J. W. Salter, Esq., F.G.S.

——— Description of a New Fossil Crustacean from the Lower Greensand of Atherfield, by Charles Gould, Esq.; communicated by Prof. Huxley, F.G.S.

Nov. 3rd.—On some Natural Pits in the Tertiary Sands of Dorsetshire, by the Rev. O. Fisher, F.G.S.

——— On the Occurrence of an Earthquake in Dartmoor, Sept. 28th, 1858, by G. W. Ormerod, F.G.S.

——— On some Veins of Granite near Dartmoor, by G. W. Ormerod, Esq., F.G.S.

——— On some Siliceous Nodules of the Chalk, by N. T. Wetherell, Esq.; communicated by the President.

Nov. 17th.—On some Fossils from South Africa, by G. W. Stowe, Esq. (In a letter to the Assistant-Secretary.)

——— On some Points in the Geology of South Africa, by Dr. Rubidge; communicated by the President.

——— On some Mineral Springs near Teheran, Persia, by the Hon. C. A. Murray; communicated by Sir C. Lyell, F.G.S.

Dec. 1st.—On the Geological Structure of the North of Scotland, and of the Orkney and Shetland Islands, by Sir R. I. Murchison, V.P.G.S.

Dec. 15th.—On the Structure of the North of Scotland. Part 3.—The Old Red Sandstone of Elgin and its neighbourhood, by Sir R. I. Murchison, V.P.G.S.

——— On the Reptilian Remains from the Sandstone near Elgin, by Prof. T. H. Huxley, F.G.S.

——— On the Succession of Rocks in the North Highlands of Scotland, by John Miller, Esq.; communicated by Sir R. I. Murchison, V.P.G.S.

——— On some Footprints in the Sandstone of Cumingstone, by S. H. Beckles, Esq., F.G.S.

1859.

January 5th.—On some Fossil Plants from the Devonian Rocks of Gaspé, by Dr. J. W. Dawson, F.G.S.

——— On some Points of Chemical Geology, by T. Sterry Hunt, Esq.; communicated by Prof. Ramsay, F.G.S.

January 19th.—On the Gold-diggings at Ballaarat, by H. Rosales, Esq.; communicated by W. W. Smyth, Esq., Sec. G.S.

——— On a New Species of Cephalaspis from the Old Red Sandstone near Ludlow, by J. Harley, Esq.; communicated by Prof. T. H. Huxley, F.G.S.

February 2nd.—On the Formation of Volcanic Cones and Craters, by G. P. Scrope, Esq., M.P., F.G.S.

After the Reports had been read it was resolved,—

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

It was afterwards resolved,—

1. That the thanks of the Society be given to Sir R. I. Murchison and Leonard Horner, Esq., retiring from the office of Vice-Presidents.

2. That the thanks of the Society be given to Thomas Davidson, Esq., retiring from the office of Secretary.

3. That the thanks of the Society be given to Dr. Daubeny, T. F. Gibson, Esq., S. P. Pratt, Esq., N. S. Maskelyne, Esq., and Colonel Henry James, 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 Officers and Council for the ensuing year :—

## OFFICERS.

*PRESIDENT.*

Professor John Phillips, M.A., LL.D., F.R.S.

*VICE-PRESIDENTS.*

John J. Bigsby, M.D.
Hugh Falconer, M.D., F.R.S.
Sir Charles Lyell, F.R.S. & L.S.
Major-General Portlock, LL.D., F.R.S.

*SECRETARIES.*

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

*FOREIGN SECRETARY.*

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

*TREASURER.*

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

*COUNCIL.*

John J. Bigsby, M.D.
W. J. Broderip, Esq., M.A., F.R.S. & L.S.
Thomas Davidson, Esq., F.R.S.
Hugh Falconer, M.D., F.R.S.
R. A. C. Godwin-Austen, Esq., B.A., F.R.S.
William John Hamilton, Esq., F.R.S.
Leonard Horner, Esq., F.R.S. L. & E.
Prof. T. H. Huxley, F.R.S.
Sir Charles Lyell, F.R.S. & L.S.
Prof. W. H. Miller, M.A., F.R.S.
John C. Moore, Esq., M.A., F.R.S.
Prof. John Morris.
Sir R. I. Murchison, G.C.St.S., F.R.S. & L.S.
Robert W. Mylne, Esq.
Prof. John Phillips, M.A., LL.D., F.R.S.
Major-General Portlock, LL.D., F.R.S.
Joseph Prestwich, Esq., F.R.S.
Prof. A. C. Ramsay, F.R.S.
G. P. Scrope, Esq., M.P., F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Alfred Tylor, Esq., F.L.S.
Rev. Prof. Whewell, D.D., F.R.S. & S.A.
S. P. Woodward, Esq.

# LIST OF

# THE FIFTY FOREIGN MEMBERS

## OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1859.

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

| Date of Election. | |
|---|---|
| 1853. | Count Alexander von Keyserling, *St. Petersburg.* |
| 1853. | Professor Dr. L. G. de Koninck, *Liége.* |
| 1854. | M. Joachim Barrande, *Prague.* |
| 1854. | Professor Dr. Karl Friedrich Naumann, *Leipsic.* |
| 1856. | Professor Dr. Robert Bunsen, *Heidelberg.* |
| 1857. | Professor Dr. H. R. Goeppert, *Breslau.* |
| 1857. | M. E. Lartêt, *Paris.* |
| 1857. | Professor Dr. H. B. Geinitz, *Dresden.* |
| 1857. | Dr. Hermann Abich, *St. Petersburg.* |
| 1858. | Dr. J. A. E. Deslongchamps, *Caen.* |
| 1858. | Herr Arn. Escher von der Linth, *Zurich.* |
| 1859. | M. A. Delesse, *Paris.* |

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## AWARDS OF THE WOLLASTON-MEDAL

UNDER THE CONDITIONS OF THE "DONATION-FUND"

ESTABLISHED BY

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

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

*Since the year* 1846, *the Medal has been struck in Palladium, in commemoration of the Discoverer.*

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

## Trust Account.

| Receipts. | £ | s. | d. |
|---|---|---|---|
| Balance at Banker's, 1st of January 1858, on the Wollaston Donation Fund | 30 | 19 | 3 |
| Dividends on the Donation Fund of 1084*l.* 1*s.* 1*d.* Red. 3 per Cents. | 31 | 14 | 2 |
| | £62 | 13 | 5 |

| Payments. | £ | s. | d. |
|---|---|---|---|
| Award to James Hall, Esq. | 25 | 19 | 0 |
| Cost of Striking, Engraving, &c. two Palladium Medals, awarded to James Hall, Esq. and Herr Hermann von Meyer | 5 | 0 | 3 |
| Balance at Banker's (Wollaston Fund) | 31 | 14 | 2 |
| | £62 | 13 | 5 |

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

THOS. F. GIBSON,
CHARLES TWAMLEY, } *Auditors.*

*Feb.* 5, 1859.

## Valuation *of the Society's Property; 31st December,* 1858.

| Property. | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Due from Messrs. Longman and Co., on Journal, Vol. XIV. | | | | 54 | 9 | 0 |
| Due for Subscriptions to Journal | | | | 65 | 5 | 0 |
| Due for Authors' Corrections in Journal | | | | 5 | 2 | 6 |
| Balance in Banker's hands | | | | 298 | 7 | 8 |
| Balance in Clerk's hands | | | | 12 | 14 | 3 |
| Funded Property, 4578*l.* 19*s.* 2*d.* Consols, at 95* | | | | 4350 | 0 | 0 |
| Arrears of Admission Fees (considered good) | 115 | 10 | 0 | | | |
| Arrears of Annual Contributions (considered good) | 100 | 0 | 0 | | | |
| | | | | 215 | 10 | 0 |
| | | | | £5001 | 8 | 5 |

| Debts. | £ | s. | d. |
|---|---|---|---|
| Balance in favour of the Society | 5001 | 8 | 5 |
| | £5001 | 8 | 5 |

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

*Feb.* 5, 1859. JOSEPH PRESTWICH, *Treas.*

* This sum includes Mr. Greenough's Bequest of £500, which was funded temporarily.

INCOME.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balance at Banker's, January 1, 1858 .... | 248 | 5 | 7 | | | |
| Balance in Clerk's hands .............. | 12 | 1 | 9 | | | |
| | | | | 260 | 7 | 4 |
| Compositions received ........................ | | | | 31 | 10 | 0 |
| Arrears of Admission Fees ............ | 86 | 2 | 0 | | | |
| Arrears of Annual Contributions ........ | 25 | 4 | 0 | | | |
| | | | | 111 | 6 | 0 |
| Admission Fees of 1858 ........................ | | | | 392 | 14 | 0 |
| Annual Contributions of 1858 .................... | | | | 567 | 10 | 6 |
| Dividends on 3 per cent. Consols .................. | | | | 133 | 18 | 9 |
| Publications: | | | | | | |
| Longman and Co., for Sale of Quarterly Journal in 1857 .............................. | 76 | 18 | 2 | | | |
| Sale of Transactions ...................... | 19 | 5 | 0 | | | |
| Sale of Proceedings ...................... | 0 | 15 | 0 | | | |
| Sale of Journal, Vol. 1–6 .................. | 10 | 8 | 6 | | | |
| " Vol. 7 .................. | 2 | 12 | 0 | | | |
| " Vol. 8 .................. | 1 | 10 | 0 | | | |
| " Vol. 9 .................. | 1 | 13 | 0 | | | |
| " Vol. 10 .................. | 5 | 18 | 6 | | | |
| " Vol. 11 .................. | 6 | 9 | 0 | | | |
| " Vol. 12 .................. | 14 | 7 | 6 | | | |
| " Vol. 13 .................. | 61 | 14 | 0 | | | |
| " Vol. 14* .................. | 182 | 17 | 1 | | | |
| " Geol. Map of England .......... | 3 | 2 | 0 | | | |
| " Library Catalogues ............ | 2 | 13 | 0 | | | |
| " Ormerod's Index .............. | 9 | 0 | 0 | | | |
| | | | | 399 | 2 | 9 |
| | | | | £1896 | 9 | 4 |

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

Feb. 5, 1859. THOS. F. GIBSON, CHARLES TWAMLEY, } *Auditors.*

| | £ | s. | d. |
|---|---|---|---|
| * Due from Messrs. Longman and Co., in addition to the above, on Journal, Vol. XIV. | £54 | 9 | 0 |
| Due from Fellows for Subscriptions to Journ. | 65 | 5 | 0 |
| Due from Authors for Corrections ........ | 5 | 2 | 6 |
| | £124 | 16 | 6 |

*Year ending December 31st*, 1858.

EXPENDITURE.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| General Expenditure: | | | | | | |
| Taxes | 25 | 11 | 10 | | | |
| House Repairs | 3 | 0 | 0 | | | |
| Fire Insurance | 8 | 3 | 6 | | | |
| Furniture Repairs | 15 | 3 | 9 | | | |
| New Furniture | 42 | 15 | 9 | | | |
| Fuel | 36 | 7 | 0 | | | |
| Light | 40 | 19 | 11 | | | |
| Miscel. House expenses, including Postages | 57 | 11 | 0 | | | |
| Stationery | 25 | 5 | 9 | | | |
| Miscellaneous Printing | 58 | 17 | 6 | | | |
| Tea for Meetings | 22 | 11 | 2 | | | |
| | | | | 336 | 7 | 2 |
| Salaries and Wages: | | | | | | |
| Assistant Secretary | 200 | 0 | 0 | | | |
| Clerk | 120 | 0 | 0 | | | |
| Assistant in Library and Museum | 39 | 0 | 0 | | | |
| Porter | 90 | 0 | 0 | | | |
| House Maid | 33 | 4 | 0 | | | |
| Occasional Attendants | 11 | 19 | 0 | | | |
| Collector | 21 | 17 | 0 | | | |
| | | | | 516 | 0 | 0 |
| Library | | | | 37 | 8 | 2 |
| Museum | | | | 5 | 16 | 8 |
| Diagrams at Meetings | | | | 11 | 16 | 6 |
| Miscellaneous Scientific Expenses | | | | 14 | 0 | 11 |
| Publications: | | | | | | |
| Ormerod's Index | 55 | 15 | 11 | | | |
| Geological Map of England | 5 | 0 | 0 | | | |
| Transactions | 5 | 6 | 4 | | | |
| Proceedings (Abstracts, &c.) | 54 | 16 | 2 | | | |
| Journal, Vols. I.–VI. | 0 | 9 | 0 | | | |
| ,, Vol. XII. | 1 | 9 | 0 | | | |
| ,, Vol. XIII. | 4 | 12 | 7 | | | |
| ,, Vol. XIV. | 536 | 9 | 0 | | | |
| | | | | 663 | 18 | 0 |
| Balance at Banker's, Dec. 31, 1858 | 298 | 7 | 8 | | | |
| Balance in Clerk's hands | 12 | 14 | 3 | | | |
| | | | | 311 | 1 | 11 |
| | | | | £1896 | 9 | 4 |

# Estimates *for the Year* 1859.

## INCOME EXPECTED.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Due for Subscriptions on Quarterly Journal (considered good) | 60 | 0 | 0 | | | |
| Due for Authors' Corrections | 5 | 2 | 6 | | | |
| | | | | 65 | 2 | 6 |
| Arrears (See Valuation-sheet) | | | | 215 | 10 | 0 |
| Ordinary Income for 1859 estimated : | | | | | | |
| Annual Contributions (182 Fellows) | | | | 573 | 6 | 0 |
| Admission Fees | | | | 180 | 0 | 0 |
| Compositions | | | | 63 | 0 | 0 |
| Dividends on 3 per Cent. Consols | | | | 133 | 18 | 9 |
| Sale of Transactions, Proceedings, Geological Map, Library Catalogues, Ormerod's Index | | | | 50 | 0 | 0 |
| Sale of Quarterly Journal | 200 | 0 | 0 | | | |
| Due by Messrs. Longman and Co. in June, for sale of Journal in 1858 | 54 | 9 | 0 | | | |
| | | | | 254 | 9 | 0 |
| Due to Library on account of Mr. Greenough's Bequest | | | | 55 | 0 | 0 |
| | | | | 1590 | 6 | 3 |
| Balance against the Society* | | | | 38 | 17 | 9 |
| | | | | £1629 | 4 | 0 |

* The £100 for the Museum and £100 for the Geological Map are not to be considered under the head of Ordinary Expenditure, being on account of Mr. Greenough's Bequest of £500, left at the disposal of the Council for special objects. The actual estimate of Ordinary Expenditure will therefore be

| | £ | s. | d. |
|---|---|---|---|
| | £1629 | 4 | 0 |
| Less | 200 | 0 | 0 |
| | 1429 | 4 | 0 |
| Balance in favour of the Society | 161 | 2 | 3 |
| | 1590 | 6 | 3 |

JOSEPH PRESTWICH, Treas.

*Feb.* 5, 1859.

## EXPENDITURE ESTIMATED.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| General Expenditure : | | | | | | |
| Taxes | 30 | 0 | 0 | | | |
| Fire Insurance | 3 | 0 | 0 | | | |
| House Repairs | 12 | 0 | 0 | | | |
| Furniture | 20 | 0 | 0 | | | |
| Fuel | 35 | 0 | 0 | | | |
| Light | 35 | 0 | 0 | | | |
| Miscellaneous House Expenditure | 50 | 0 | 0 | | | |
| Stationery | 25 | 0 | 0 | | | |
| Miscellaneous Printing | 40 | 0 | 0 | | | |
| Tea for Meetings | 23 | 0 | 0 | | | |
| | | | | 273 | 0 | 0 |
| Salaries and Wages : | | | | | | |
| Assistant Secretary | 200 | 0 | 0 | | | |
| Clerk | 120 | 0 | 0 | | | |
| Assistant in Library, &c. | 40 | 0 | 0 | | | |
| Porter | 90 | 0 | 0 | | | |
| House Maid | 33 | 4 | 0 | | | |
| Occasional Attendants | 12 | 0 | 0 | | | |
| Collector | 22 | 0 | 0 | | | |
| | | | | 517 | 4 | 0 |
| Library, New Books, &c. | 40 | 0 | 0 | | | |
| Museum, Ordinary Expenditure ... £ 30; „ Special Expenditure* ... £100 | 130 | 0 | 0 | | | |
| Diagrams at Meetings | 12 | 0 | 0 | | | |
| Miscellaneous Scientific Expenses | 12 | 0 | 0 | | | |
| Publications : Quarterly Journal | 500 | 0 | 0 | | | |
| „ Transactions | 5 | 0 | 0 | | | |
| „ Proceedings | 40 | 0 | 0 | | | |
| „ Geological Map* | 100 | 0 | 0 | | | |
| | | | | 839 | 0 | 0 |
| | | | | *£1629 | 4 | 0 |

# PROCEEDINGS

AT THE

## ANNUAL GENERAL MEETING,

18TH FEBRUARY, 1859.

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### AWARD OF THE WOLLASTON MEDAL AND DONATION FUND.

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AFTER the Report of the Council had been read, the President, J. PHILLIPS, Esq., M.A., LL.D., F.R.S., placed in the hands of Sir C. LYELL the Wollaston Medal awarded to CHARLES DARWIN, Esq., saying:—

SIR C. LYELL,—To no one can the Medal which is destined for Mr. Darwin be committed with so much justice as to yourself, who, like him, have carried the fame of this Society over distant lands, and, like him, have always looked on the phænomena of nature with a comprehensive survey, a minute attention, and a just appreciation of the dignity of our science. Mr. Darwin, ever since his great abilities became known by the "Researches during the Voyage of the 'Beagle,'" has never ceased to labour, even in spite of ill health, in the cause of geology. We owe to him the admirable observations on Coral-growth, which led to the grand speculation of alternate zones of elevation and depression in the Pacific and Indian Oceans. He has given us data for the modern elevation of Chili, for the often repeated elevations of the Andes and the bordering regions; through great tracts of America his masterly hands have sketched and measured the prominent structures of rocks; in the British Islands he has studied the distribution of boulders, the change of level of land and sea, the parallel roads of Glen Roy, the course of ancient glaciers. I might enumerate many other of his judicious and vigorous efforts on some of the harder problems of geology; but it is enough to mention one of his latest labours, which combines the rarest acquirements as a naturalist with the qualifications of a first-class geologist. The admirable monograph on the *Cirripedia*, which adorns the volumes of the Palæontographical Society—one of the most remarkable in these volumes—has added much to a reputation already raised to the highest rank. I have great pleasure in thus bearing public testimony to the noble works of that Society, which has been able to secure the zealous services of such men as Darwin. Let Mr. Darwin be assured that we hope to welcome him often in better health, and personally to renew the congratulations which must be agreeable to him when received through the hands of one of his earliest friends and most illustrious fellow-labourers.

Sir C. Lyell having received the Wollaston Medal from the President, replied:—

Mr. President,—I thank you, Sir, for the kind and complimentary manner in which you have spoken of me and my labours; and on the part of my friend Mr. Darwin, I have been requested by him to acknowledge his gratitude for the high honour conferred on him, which, he says, comes the more unexpectedly because the state of his health has made it impossible for him to attend the meetings of the Society, or to have intercourse with its members as frequently as he could have wished. But the Wollaston Medal, he adds, is the more prized by him as a mark of your sympathy, because it cheers him in the seclusion in which he finds it necessary to pursue his studies and researches; and at the same time, in thanking you for the honour, he says he shall consider it not so much as a reward deserved for work already done (a sentiment in which we shall not agree with him), as an incentive to future exertion.

The President then delivered to Sir Roderick Murchison, for the use of Mr. Charles Peach, the balance of the Proceeds of the Wollaston Fund, addressing him in the following words:—

Sir R. I. Murchison,—To you, Sir Roderick, who have watched with interest the zealous labours of Mr. C. Peach, who have personally known his good qualities, and who have employed in your latest work some of his latest discoveries, we commit this slight acknowledgement, in testimony that the Geological Society knows and values the efforts of its children, whether they work at the Land's End of the Cornubii, or at the northern extremity of Caledonia. In each of these districts Mr. Peach has been a real and sagacious discoverer; from each of these districts he has generously and immediately communicated the new knowledge he had gathered; and in each of these districts his modest and manly worth have won him true friends and honest admirers. Were this purse as full of good coins as his communications on Palæontology and Marine Zoology have been full of precious truths, it would better express the estimation in which we hold him and his labours.

Sir R. I. Murchison replied as follows:—

Sir,—On the part of my friend Mr. Charles Peach, to whom the Council unanimously adjudicated the Proceeds of the Wollaston Fund, I am requested to express to you his most grateful thanks for an honour which he had not the remotest idea of ever obtaining, and which, he says, will serve as a powerful stimulus to his future exertions.

As the terms employed by the Council in awarding this prize, enlarged upon as they have been so ably by yourself, have sufficiently explained the grounds on which we acted, permit me, who have been a close observer of the career of Charles Peach, to state that his merits seem to me to be precisely those which respond to the intentions of the illustrious testator. We have, in truth, granted this Wollaston Purse to a man who, possessed of very slender means, occupied with onerous public duties, and charged with the cares of a family which he has thoroughly well educated, has proved not only how much he could accomplish during leisure hours, but who has shown that, even when employed in the arduous task of visiting wrecks on wild headlands, he could detect fossils where no one ever saw them before, and has thus enabled us to assign to hard and crystalline rocks, the age of which was unknown, a definite place in the Palæozoic Series.

From having been accompanied by Mr. Peach in exploring bold coasts and lofty mountains, I can testify that boundless zeal and activity are associated in him with a quickness of eye, a rapidity of mental perception, and originality of thought, which render his services invaluable in the endeavour to develope the geological structure and relations of any country.

To these qualities let me add, that wherever he has been placed in the execution of his duties, whether near the Land's End of Cornwall or the northern extremity of Scotland, he has invariably won the regard and affection of the inhabitants, every one of whom, as well as myself and other men of science who know how to value the man, will rejoice that we have thus rewarded the ingenious, modest, and highly deserving Charles Peach.

## THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

Gentlemen,—The Report of the Council has already made you acquainted with the losses in our ranks occasioned by the decease of Fellows of the Society during the past year. Among the names are some which must occasion deep regret, soothed by profound admiration. It is indeed in other circles that these sentiments may be more strongly expressed; but here we can never be indifferent to the loss of a prince of botany like Brown, or a leader in mathematics like Peacock, or a man of letters and science, giving his laborious mind to the affairs of his country, like Warburton.

On the present occasion my remarks will be very limited; the part taken by our deceased Fellows in advancing the special objects of our science being, even in the case of Mr. Warburton, only incidental.

Robert Brown, M.A., F.R.S., D.C.L., born at Montrose 21st December, 1773, died 10th June, 1858, full of years and of honours. The immense and well-earned botanical knowledge of Dr. Brown was turned to good account in geology by his friend Dr. Buckland, both in the notice of fossil plants in the Bridgewater Treatise, and in the paper on Cycadeoïdeæ, which adorns our Transactions *. To the subject of fossil botany he was, indeed, specially attached; always glad to receive the additional information which new remarks, and especially new specimens, could furnish; always ready, but at the same time cautious, in giving his views on the difficult questions frequently suggested by fragments of unknown plants. His large collection of specimens of fossil woods is bequeathed to the British Museum.

Herbert Francis Mackworth, born 27th September, 1823, in Trinidad, died 13th July, 1858. Mr. Mackworth was educated at King's College, London, and was appointed Inspector of the Mines and Collieries in the southern district of England and Wales in 1851, an office for which he had prepared himself by previous employment as an engineer, and several visits to the mining districts of England and Germany.

Hugh Lee Pattinson, born at Alston Moor in Cumberland, and trained up to mining and metallurgy, distinguished himself by the invention of a new and economical process for the separation of silver from lead. He was a practical chemist and electrician, and a liberal promoter of astronomy. Died 11th November, 1858.

The Rev. George Peacock, D.D., Dean of Ely, born 9th April, 1791, at Thornton Hall, Denton, in the parish of Gainford, near Darlington, Durham, died 8th November, 1858.

Though the late Dean of Ely contributed no paper to the Geological Society, he gave to geology in the British Association the valuable support which might be justly claimed of a profound mathematician, on behalf of a branch of knowledge, some of whose highest generalizations are based on astronomical truths, and whose special phænomena often involve researches into the laws of heat, the mechanical conditions of rocks, and the interpretation of numerical results.

Henry Warburton, M.A., F.R.S., born in London, educated at Eton, and Trinity College, Cambridge, died 21st September, 1858, aged 74. Devoted through a considerable part of life to the labours of a Member of Parliament, he retained till the end the exceeding love of classical literature, and the strict habit of scientific thought which had been inspired by his University course. These qualities were manifested rather in his personal intercourse with the Fellows of the Geological Society, than by his contributions to our volumes. In fact, the addresses which Mr. Warburton read as our President, in 1843 and 1844, have not been printed; and the considerable share which he really took in our labours is but feebly

* Geol. Trans. series 2, vol. ii. p. 395.

shown by the papers which we were fortunate enough to obtain from his perhaps too fastidious hands *.

GEOLOGY, spreading with the growing intercourse of nations, is constantly enlarging its field of observation, and gathering its characteristic facts into laws of phænomena. From time to time, as opportunities arise for successful research, or as some stand-point for the interpretation of facts is fixed by chemistry, or mechanical philosophy, or comparative physiology, the progress of our researches is more marked in one direction than another. At one time, following the guidance of mathematical reasoning, we try to arrive at trustworthy results regarding the internal constitution of the globe; anon, with surer aim, we bring into strong relief the long succession of mineral deposits and the changes which they have experienced by the incessant energies of nature operating through immensity of time; and we coordinate this succession and these changes with the series of ancient organic life and the physical condition of the globe.

After seventy years of labour, the series of British strata—than which none is more complete—has become known in its true general sequence and in its principal local variations. The large tracts of primary strata in Wales, which eluded the strong grasp of Smith, have been probed to their thinly fossiliferous base by Sedgwick and Murchison, and the Geological Surveyors treading in their steps; strata of equal antiquity in Ireland have yielded a small suite of organic remains to the diligent followers of Griffith; and the latest work of Murchison, completing this toilsome labour, is the tracing in Scotland of metamorphic rocks in a zone below *Maclurea* and the oldest fossils of North America. If in this long research we have not certainly reached an Azoic condition of the globe, we have rendered it probable that such a condition did once obtain, because the sum of the series of life, whether taken numerically, or by physiological valuation of the several terms, diminishes as we go downwards, by such a gradation as to point finally to zero. From this point upwards, in the whole series of British strata, there is hardly one stratum whose place is doubtful, one place of which the subjacent rock is quite unknown. There are few districts and few strata whose fossils are without record; few fossils whose distribution in space and in time is not to some extent ascertained. In this vast research the Geological Society has laboured for more than half a century with well-rewarded patience, yet still has before it a mighty and pleasing labour, in fields opening ever freshly to view. Every tract may be again surveyed with advantage, every rock be re-examined for testing some law and confirming some truth.

Exulting as we must do in the brilliant achievements of the Geological Survey, and pointing to the beautiful maps which already

* "On Magnesian Breccia," Geol. Trans. ser. 1. vol. iv. p. 205.
"On some beds of Shell-marl in Scotland," Geol. Trans. ser. 1. vol. iv. p. 305.
"On Volcanic Chromate of Iron," Geol. Trans. ser. 1. vol. v. p. 616.
"On the Bagshot Sand," Geol. Trans. ser. 2. vol. i. p. 48.
"On a bed of Septaria in Plastic Clay," Quart. Journ. Geol. Soc. vol. i. p. 172.

occupy Wales and cover so large a space of England and Ireland, as valuable data to the miner, farmer, merchant, and engineer,—to us these maps have the value of contributions toward the ancient hydrography of the world, the ancient lines of violent earth-shakings, the ancient boundaries of life. And, thankful as we are to the persevering energy of the Palæontographical Society for some of the noblest monographs of organic remains which have ever appeared, to us these great works are but precious data toward the history of life and the changes of life, in the long series of geological time, and the long series of physical changes. These changes again grow under examination into a new and great field of research—passing beyond observation at the surface of the earth, to reasonings on the condition of its interior masses—to investigations of the reaction of these on the surface, and their effects in the eruptions of melted rocks, the metamorphism of strata, and the production of mineral veins.

It is not to be supposed that all these trains of inquiry are to be equally exemplified in the contributions to our Society in the course of one official year: such equality is not desirable; it might be associated with indifference.

From the large mass of subjects thus noticed as deserving the attention of geologists, observers in the British Isles, following the instinct of the inductive philosophy, have commonly selected for serious work those which promise to yield positive laws, however limited, as bases for theory and guides for practical operations. Why do we engage so earnestly in the preparation and verification of geological maps and sections, if it is not because these are on the one hand the trustworthy data for marking out the ancient boundaries of land and sea, and on the other the surest means of advancing mining, architecture, agriculture, and many useful arts?

In England, rich in organic remains, and in many natural exhibitions of the whole series of fossiliferous strata, the main tendency of geological exertion has for some years been in the direction of palæontology. To form complete and critical catalogues of British fossils,—to determine for each species its law of distribution in geographical space and geological time, and its dependence on physical conditions, has been found worthy of the long and serious labours of our Bell, Bigsby, Bowerbank, Bunbury, Darwin, Davidson, Egerton, Forbes, Falconer, Fitton, Hooker, Huxley, Jones, Lonsdale, Morris, Owen, Prestwich, Salter, Woodward, and Wright. By them, not only our own proceedings have been enriched, but we are able to point with satisfaction to separate works of eminent usefulness and merit, and whole volumes of precious monographs published by the Palæontographical Society.

As an example of the good effect of the union of these branches of geological study, I would instance the late republication of the great work on 'Siluria' by Sir Roderick Murchison; for here we have, consolidated under the contemplation of one mind, and that the most fitted for the task, the whole series of palæozoic history, and a great part of the evidences clearly digested and perfectly illustrated. If we might have monographs on a similar plan of completeness embracing other great divisions of our geological system, each the work of the man most prepared for the task, geology could never again appear other than it is—a firm and coherent structure of truths reared on an ample and adequate basis of observed facts. One of the most acceptable parts of this very complete work is the excellent table of the geological distribution of the Silurian species of fossils, drawn up with minute accuracy by Mr. Salter.

In like manner I must call attention to the admirable volumes, with maps and sections, by Prof. H. D. Rogers, which display, on a scale of splendour worthy of so great a State, the geology of Pennsylvania. If we consider the date when this great undertaking began (in 1836), and the toils and difficulties through which our distinguished friend and fellow-labourer has won his way to the magnificent result which has been placed this day before us, our congratulations at this happy completion of so great a work will be mixed with cheerful hope that hereafter the sheets of our own Survey may be as fully illustrated by contemporaneous descriptions of rocks and fossils, and phænomena observed in the field. The good examples set in this particular by Portlock and De la Beche have been, indeed, in some respects carried out by special memoirs in illustration of some parts of England and Wales; and the Director-General of the Survey has taken so much interest in this subject, that I hope it may be found practicable to obtain authentic notices of every sheet of the Survey of several districts formerly surveyed, mapped, and illustrated by sections; for we are still in want of those descriptive pages which might have been issued with the sheets and the sections, but can never be well supplied by memory or recovered from note-books, after the lapse of years and the pressure of other engagements.

Ireland, rich in the minerals which accompany the plutonic and metamorphic rocks of its romantic coasts—rich also in the excellent map of Sir R. Griffith,—has of late years added to active palæontological research a revived attention to mineralogy. The zeolitic products of Antrim have engaged the attention of Andrews and Apjohn*. Haughton and Galbraith have examined the felspars and micas in the granites of Wicklow†; and Gages has been engaged in tracing the exact progress of metamorphism in several cases where it was little expected, by methods not less ingenious‡ than those employed by Mr. Sorby in scrutinizing the gas- and water-cavities in the constituents of many rocks§.

In Scotland, the recently published map of Prof. Nicol, with the compendious note on Scottish Geology which accompanies it, will be found of great service in the still unanswered questions suggested by its strongly-marked physical features, its amazing areas of meta-

* Reports of Brit. Association, Proc. Geol. Soc. of Dublin, &c.
† Phil. Mag. and Annals, *passim.*
‡ Reports of Brit. Association, 1858.
§ Quart. Journ. Geol. Soc., 1858.

morphic rocks, its vast fields of trap, its detached fragments of mesozoic strata, its successive stages of glacial emergence and depression, and the singularities of its palæozoic fauna. Judging from the contributions made to the Society in the last year by Mr. Moore*, Mr. Brown†, Mr. Jameson‡, Mr. Miller§, and to the British Association, at their Leeds Meeting, by Mr. Page and Dr. Anderson‖, there is no reason for doubting that these questions will all in due time be fully and accurately answered.

Thanks to the continued labours of the Geological Survey, the great map of England and Wales by W. Smith, now nearly half a century old, followed by those of Greenough, Griffith, and Macculloch, has been expanded into a magnificent national work, already spreading its branches into our colonies of Canada and Australia, and our Indian possessions in the East and the West. In this labour we are only proceeding *pari passu* with other European and Transatlantic Powers; so that, wherever civilization spreads the arts of life and the studies which dignify humanity, this the fundamental work of geology is steadily and carefully prosecuted—" *Quæ regio in terris nostri non plena laboris?*"

Nearly twenty years have passed since the map which Mr. Greenough bequeathed to the Society was published in its amended form. In the interval, some changes have occurred in the general classification of strata, and many improvements have become requisite in the details of the map.

The Council has entrusted to a Committee the task of renewing it. In this undertaking, the intention of the author to make it a record of the state of geological survey in England and Wales has been kept in view. The results of the great Survey which has now been in progress for upwards of twenty years have been taken as the basis, and, as well as could be done, on a scale so much reduced, have been transferred to our map. Thus the two sheets now placed for inspection were nearly filled, and the small space left uncompleted in one of them near Manchester has been coloured by Mr. Binney. The work of the National Survey goes beyond these sheets; and the Committee has taken measures to obtain approximate corrections of the whole of the remaining area, by requesting from individual members of the Society to be favoured with the valuable aid of their personal, often as yet unpublished knowledge.

A geological map in sufficient detail is a severe test of the actual state of our science. It requires positive determinations—not probable views—fixed classifications of strata—exact limitations of the old sea-deposits—of the old areas of vertical displacement—of the effect of metamorphic action. It will be long before even the best and greatest of our maps can fulfil all the purposes of the miner, the farmer, the engineer; but they are already in such a state of

* On the Silurian Rocks of Ayrshire.
† Section of the Coast of Fife.
‡ On a Lias Outlier near Banff.
§ On the Rocks of the Northern Highlands.
‖ Reports of the British Association, 1858.

comparative excellence, as to be of indispensable use to these and other parts of our social system.

The principal difficulty is in the district of the English Lakes, which, though examined by many geologists since it was fairly opened by Otley, and Sedgwick, and Smith*, is still one of the parts of this country which are least accurately mapped†. In the boundaries of the granites and syenites, in the ranges of trap-rocks, in the geography of faults and axes of movement, Prof. Sedgwick is not only the highest, but, in fact, for many parts the only authority. May we cherish the hope that the remainder of his work in a district so dear to his memory will be completed by additional memoirs in our Proceedings, already rich in monuments of his genius and industry! ‡

During the last few years, the exact limits of the Devonian and other large groups of British strata have been made the subject of discussion and local examination. As an example may be quoted the researches of Prof. Jukes, Mr. Du Noyer, and Mr. Kelly, on the Old Red Sandstone of Ireland. One of the more prominent inquiries of this nature has been brought before the Society during the past session by Sir Roderick Murchison and Prof. Huxley. The former geologist has taken great pains to ascertain the true classification of the older strata of Scotland (in this often concurring with Prof. Nicol, whose excellent map, lately published, will be of the greatest service to geologists), and in particular the true place in the series of the upper sandstones of the coast of Elgin, Nairn, and Banff. These he decides to be of the Upper Devonian series. In them he found bones of a reptile—not, like the *Telerpeton* of the same region, a small, possibly batrachian lizard, but an animal of large size. These Prof. Huxley, having fully examined them, finds to be sufficiently well preserved (casts of the outside generally) to serve as secure ground for arguments of analogy,—parts of a jaw, limbs, the vertebral column, and ventral and dermal scuta. Judging by these distinct remains, he infers the animal to have had important affinities to the higher Reptilia, and especially those *Crocodilians*, which, like *Teleosaurus*, had a rich armature of deeply pitted bony scuta covering the whole body. In some particulars, analogy is found to the *Deinosaurians*; and though the reptile of the Lossiemouth quarries is not really a *Teleosaurus* or a *Megalosaurus*, and seems indeed to be of a peculiar combination not previously met with, still it presents enough of correspondence to the mesozoic fauna, and perhaps even to the reptiles of the Oolite, as to awaken some

* See the maps of Cumberland, Westmoreland, and the Lake district, coloured by W. Smith, 1821—1822, &c.

† See map by John Ruthven (from data communicated by Sedgwick), in Miss Martineau's 'Guide to the Lakes.'

‡ On the evening of Nov. 17, 1826, Prof. Sedgwick read to the Geological Society the important paper on the Magnesian Limestone Series of the North of England, which first settled the true relations of that remarkable group of deposits. I was then allowed to attach some palæontological notes to this work; and now, after enjoying for so many years his unchanging friendship, I feel the truth of the expression "Est aliquid . . . . a Diomede legi."

surprise in the palæontologist. I think it fair to the authors of these two remarkable communications, to request that no more weight may be placed on their general views than they wish them to carry. At present, it seems that mesozoic vertebral structure has been found deep in palæozoic strata; but there is still a chance that these strata may be ultimately found to be of less antiquity; and there is still something to be added to our knowledge of the fossils before we can fully declare the sum of their affinities.

In England and Wales, fortunately for the progress of our map, there is no difficulty in settling the boundaries of the Old Red Series, except in those tracts of Devon and Cornwall where the usually red series of sandstones, shales, and conglomerates is varied by bands of protoxidated sediments, and modified by cleavage and metamorphic action. To this day we are insufficiently informed of the limits of the probably small area of the Silurian rocks in the southern parts of this tract. Nor have we an exact determination of the upper limit of the Devonian rocks in contact with the carboniferous limestone and shale of Barnstaple, though probably the nearly united opinion of Lonsdale, Murchison, Sedgwick, and myself, which leaves the Pilton and Petherwin beds as Devonian, may be regarded as the most general view. It is adopted on the map.

Among the singular phænomena which have been ascertained within no long time, touching the geographical ranges of strata, may be mentioned the occurrence below the Tertiary and Cretaceous series at Harwich, of indurated carboniferous shales traversed by slaty cleavage,—part of the subterranean range of the palæozoics of North Devon, or South Wales, and, like them, containing *Posidoniæ*.

A great change will appear on the new map in reference to the Permian deposits, which, according to the labours of Prof. Ramsay and the Government Survey, spread over much larger space in the Midland Counties than was formerly conceded to them. In a sandy and conglomeratic form they are represented as occupying large tracts formerly assigned to the New Red Sandstone.

If there be still a want of accordance among geologists as to the association of the bone-bed of Aust,—the fossils, according to Egerton, indicating Triassic affinity, while the nature of the matrix perhaps refers them to the Lias,—this does not affect our map. A point of some difficulty occurs at the upper boundary of the Lias, where the thick and peculiar sands which occur near Bath present affinities in two directions—upwards to the Oolite, downwards to the Lias. We have thought it best to preserve the sands in their ancient geographical allegiance to the Oolite, *on the map*; but we do not intend by this to pronounce on the value of the evidence of the Cephalopoda and other fossils which has been of late collected, and is still under consideration, by Prof. Buckman, Dr. Wright, and the palæontologists of Gloucestershire.

Two observations which have been communicated to the Society during the last session show how very far beyond their actual boundaries some of the mesozoic strata, composed of fine sediments, formerly extended. Mr. Jameson has made us acquainted with the existence of a patch of Lias in Banffshire. Another unexpected and equally interesting fact has been ascertained by Mr. Binney—the occurrence of Lias on the Trias of the plain of Carlisle, like that far-separated tract which Murchison made known on the red marls of the Cheshire plain. This discovery is the more important, as leaving no room for doubt as to the true age of the red marls and sandstones of the plain of Carlisle. They are certainly Triassic, and, like those of the Vale of Clwyd, lie at the foot of a chain of hills thrown up before their date; among the dislocated beds we find the Permian calcareous conglomerates. *Do they cover coal?*

The important share in the accumulation of the materials of the strata which is due to the action of ancient currents and surfaces of fresh water has become fully recognized. In a table some time since drawn up by Prof. Ramsay*, the deposits of fresh water, pure or mixed with estuarine or littoral deposits, have been ranged in order, and we see that from the Middle Palæozoic era at least, traces of this action are apparent in every period. There seems likely to be always a difficulty in giving exactness to conclusions regarding the date of these deposits, where they do not alternate with the marine strata which really mark the scale of geological time. This kind of doubt remains to some extent in regard to the freshwater and estuarine beds of Shotover †; for, though they rest upon Portland beds, and are covered by Cretaceous strata, we have rarely found critical marks for the exact age of the latter. The observation of W. Smith, made nearly sixty years since, of Gault fossils overlying the sands at Steppingley Park, is of value in narrowing the limits within which to define the age of the sands of Woburn and Shotover.

I must not conclude this notice of maps without calling your attention to the very instructive example furnished by Mr. Mylne of a local map, on a scale of magnitude adequate to practical purposes. The Map of the Geology of London will probably be copied on many occasions hereafter in other cities, where questions of importance touching the health and internal economy of the crowded masses of men shall have acquired the attention they deserve. I should also much wish to see produced some maps of estates coloured geologically, on the model, now a quarter of a century old, of the admirable map of Hackness by William Smith.

I take this opportunity of expressing my extreme gratification at the completion of that labour of love, the Classified Index to our publications, for which we are indebted to Mr. Ormerod. This work is perhaps the more important, as the Journal of the Society will in future be issued to all the resident members, and will therefore have a wider circulation.

## *Constitution of Rocks.*

Among the subjects which have acquired prominence during the past year, I wish to distinguish on this occasion, as specially deserving long and careful study, the chemical composition, molecular

* See Edinb. New Phil. Journ., new series, vol. iii. p. 315.
† Phillips in Quart. Journ. Geol. Soc., 1858.

constitution, and structure of rocks. On questions of this sort our obligations are eminently due to the geologists of France and Germany. Cordier and Brongniart, Leonhard, Senft, and Cotta, have founded upon the mineral constitution of rocks systems of classification and nomenclature, especially for rocks of igneous origin, more definite than those commonly employed in this country. Here, on the other hand, we have gradually advanced to the first place in the history of rock-structure, and especially of that interesting part of it known as slaty cleavage.

The existence of cavities containing fluid has been long since ascertained in many minerals of frequent occurrence, as, for example, fluor-spar and quartz, the former an abundant crystallized mass in the lead-mines of the north of England, the latter very common in the tin- and copper-mines of Cornwall. To Sir David Brewster we owe the first accurate steps in the delicate and difficult research into the nature of the liquids and gases which fill these cavities. The cavities in quartz are sometimes large enough to allow of the contents being examined chemically. Sir H. Davy found the liquid to be water with saline matter; Mr. Fox, water with chloride of sodium; others have discovered water with various earthy and metallic sulphates and chlorides.

The cavities are seldom full of the liquid—there is usually a bubble of air, which, except when the cavity is very small, changes place when the position of the crystal is altered. We may suppose with Mr. Sorby that the cavity was originally filled with the liquid, when the consolidation of the crystal happened, at a temperature more or less elevated above the actual temperature; that it has since contracted during the cooling, and now occupies a space which, as compared to the whole cavity in the crystal, is determined by the actual temperature as compared to the original temperature of consolidation—nearly in this proportion, not strictly, because pressure alters the bulk of a liquid, and the pressure during the formation of the crystal is unknown.

The effect of pressure, however, on the volume of water is known; supposing a case in which the pressure is known not to have been great, the temperature of consolidation may be found approximately. In the case of igneous and metamorphic rocks, Mr. Sorby finds this temperature unequal in different cases, but rising upwards to the heat of dull redness.

Assuming in this way some fixed temperature as that of consolidation for a given crystal, and measuring the relative bulk of the liquid and the cavity, we can determine the pressure, and consequently the depth, under which the rock was formed and solidified; and this depth in the case of granite is found to be so great as to correspond well to the opinion which has been adopted on other grounds of its deep-seated plutonic origin*.

Far down in the earth, then, water has been present during the formation of the rock—that is to say, the elements of water; and

* See Mr. Sorby's investigation, worked out numerically, in Quart. Journ. Geol. Soc., Nov. 1858.

on the separation of the several parts this combination—water—has been formed, and set apart during the solidification of the crystals, especially of quartz. The rock has not been formed by or in water, but water has been formed in the rock. The presence and abundance of oxygen has been long known; what the enclosed liquid tells us further is the presence of hydrogen.

Other liquids besides water occur. In one case, of amethyst, the cavity being three-fourths full of liquid at ordinary temperature, becomes full of liquid at 83° F.; on being cooled again the vacuity reappears in the crystal, with signs of ebullition*.

Naphtha and bitumen occur in other crystals.

Perhaps hardly anything is more essential to a good classification of igneous and metamorphic rocks than a correct notion of the minerals known to geologists as felspar; for this is now rather a large family of varying chemical compounds whose crystalline structure includes several types†. In a general sense, granite usually contains orthoclase-felspar, with potash; but there are cases where one of the constituents is albite or soda-felspar; and it appears that an orthoclasic crystal may have soda in its composition. We are indebted to Prof. Haughton and Mr. Galbraith for the most continued observations on this class of subjects in, as well as on the varieties of mica in the granites of, Ireland. The microscope, with polarized light and other optical means, will probably be usefully employed in the anorthic felspathic minerals which are so common in diorites and greenstones.

The arrangement of the materials which compose a stratified rock is one of the subjects for which the British strata offer many advantages, and promises of important results. By this study well prosecuted, we may distinguish between sands drifted by wind or deposited by water,—the rapid accumulations along the sea-shore, or the slow subsidence of finer sediments in deeper water, to which Mr. Babbage has lately called our attention‡. We may determine the direction of sea-currents, conjecture their form, extent, and origin, and the situation and physical character of the region whence rivers flowed into estuaries, or from the shores of which the waves transported detritus from old deposits to form new strata in other situations.

No one has been more successful than Mr. Sorby in observing phænomena of this kind, or more ingenious in applying to them interpretations in accordance with the laws which are known to govern the operations of moving water. In the Oolitic tracts of Gloucestershire, in the arenaceous deposits of the same age, and of the Magnesian and Older Carboniferous period in Yorkshire, the strata are often full of oblique lamination, due to shallow currents of water operating on easily moved sand, comminuted shells and corals, or other small bodies. By a careful study of these charac-

* Sir D. Brewster, Ed. Roy. Soc. Trans., and Ed. Phil. Journ. ix.

† See the classification of felspathic minerals by the ratios of the oxygen in their component elements, by M. Ste.-Claire Deville, in his 'Etudes de Lithologie.'

‡ Quart. Journ. Geol. Soc. vol. xii. p. 366.

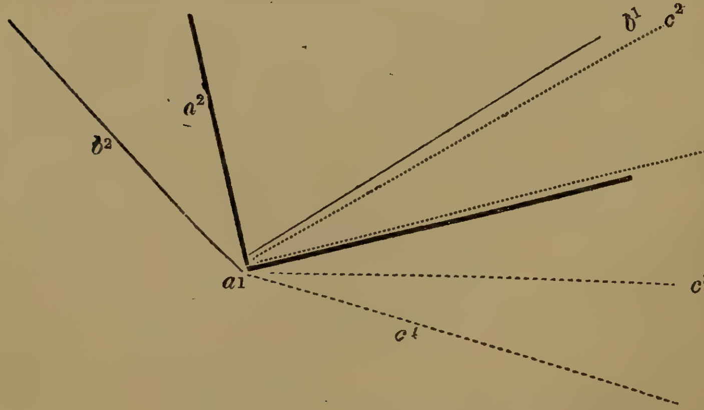
teristic accumulations, especially in Yorkshire and Derbyshire, Mr. Sorby has been able to determine within no very wide limits of error, the probable depth of water, and the direction of the currents by which the strata were deposited. In some cases the changes of the direction of the laminæ point to tidal action over and around shallow sand-banks; in others a prevalent direction of wind is recognized; and in a majority of cases such a determinate set of current as to assist in forming a map of the ancient sea-soundings.

Thus in the Millstone-grit series of Yorkshire and Derbyshire a very uniform general current from the north-east is recognized, slightly interfered with by a tide setting from the north-west, and by the action of surface-waves and wind-drift-current produced by powerful westerly gales. During the deposition of the Magnesian Limestone the sea appears to have been subject to a very decided tide, rising and falling with great uniformity from W.S.W. to E.N.E., amongst a number of shoals on which surface-waves stranded, chiefly produced by easterly winds *.

No part of the British Isles—no part of Europe, indeed—is more remarkable than Ireland for great and repeated foldings of the Palæozoic strata of all ages. It suffices to look on Mr. Griffith's map and sections to perceive the important effect which this structure produces on the physical geography of Kerry, Cork, Waterford, and other counties,—the ranges of hills, the inlets of estuaries, the course of rivers, the sites of population. In the same region slaty cleavage is often prominent, and jointed structures prevail. Professors Jukes, King, and Harkness have surveyed the joints and the cleavage in many situations; and Prof. Haughton has submitted these structures as they occur in Waterford to a geometrical scrutiny. The district selected for the purpose is the Old Red Sandstone tract of the county of Waterford. In this tract are nineteen faults, reducible to two pairs of rectangular systems. The bearings are—

($a^1$) E. 7° 30′ N. ($a^2$) N. 3° 45′ W.
($b^1$) E. 34° 22′ N. ($b^2$) N. 33° 24′ W.

The average strike of the beds is E. 10° 46′ N. The cleavage-planes




* Report of British Association for 1858.

and joints are also reducible to conjugate systems, four in number, two of them nearly agreeing with the above system of faults.

In the annexed diagram the more remarkable directions of faults and cleavage-planes appear together:—$a^1$, $a^2$, and $b^1$, $b^2$, rectangulated fault systems; $c^1$, $c^2$, $c^3$, $c^4$, directions of cleavage-planes.

From the whole examination it is concluded that the cleavage-planes are perpendicular to the axes of maximum force; that they were developed while the substance of the rock was soft; and that the joint-planes, which are conjugate to the cleavage-planes, formed by the shrinking of the rock-mass, were subsequent to the cleavage-planes, and formed while the rock was hard. The two systems of conjugate faults are regarded as the result of two distinct systems of upheaving force in the district.

In all these conclusions Prof. Haughton is much in accordance with what has been delivered on some of the subjects by Mr. Hopkins, and with phænomena observed in other districts. I have pointed out one very general similar conjugate system of joints in the North of England, and a rectangular relation of one set of joint-structures to cleavage-planes in North Wales; more than one instance of the coincidence of cleavage-planes and great faults is on record; but it is now for the first time that we have had these phænomena carefully examined as a whole, and combined into a general view of the requisite mechanical conditions.

The general conception of the law of slaty cleavage is completed by Prof. Haughton's investigation of the direction of pressure in a cleaved rock where organic remains have suffered distortion. For the purpose of recording accurate data on this subject fit for complete computation, it is necessary to measure the strike and dip of the strata, the strike and dip of the cleavage, and to determine the amount of distortion which the figure of an organic body has undergone on each of two planes of bedding, making different angles with the plane of cleavage. It is easy to deduce from these data the amount of change of dimensions which the rock has undergone.

By assuming the change of dimension to be only in the direction perpendicular to cleavage, the determination of the distortion on one plane of bedding will be sufficient to determine the amount of compression.

*Plants.*

The interesting flora of the Palæozoic strata has received much attention from the geologists of America, especially Dr. Dawson, who finds in the Devonian strata of Gaspé, besides plants clearly of the family of *Lepidodendra*, others, probably also Lycopodiaceous, which he terms *Psilophyton*. The internal structure shows cellular tissue and obliquely striated vessels; the branches are somewhat curled at the tips; the rootlets spread into the argillaceous earth, as the roots of *Stigmaria* do into fireclay. Mr. Salter informs me that in the Old Red strata of Caithness he has recognized plants of the same genus. There is another curious plant, which is of the Coniferous order, having dots on the vessels in a single series, and accompanied by oblique striation, in this respect resembling the woody tissue of the Yew; it receives the name of *Prototaxites Logani* *. We are indebted to the same observer for additional notices regarding the plants of the true Coal-measures. Mr. Binney † has added some new facts to the history of *Stigmaria*, which owes so much to his labours; Mr. Morris ‡ describes a Fern with unusual neuration from Coalbrook Dale; some details are given by myself of a fruit from the Wealden of Swanage; and Mr. Bunbury § has contributed the results of a careful examination of the fossil tertiary plants of Madeira, which manifest a great general analogy with the actual flora of the island.

The fossil plants of the Jurassic beds of the Venetian Alps have become the subject of an interesting essay by De Zigno, who finds them to be closely allied to the plants of the Oolitic series of Yorkshire; thus confirming the law now so generally accepted, which leads us to expect over large geographical areas similarity of specific forms of life in strata of equal antiquity.

In the study of the remains of ancient vegetation, more than ordinary difficulties are to be encountered. Seldom do we find more than fragments in their native repositories; the soft or brittle material which encloses them is liable to fracture; the surface of deposit exposed is usually very small; and the whole collection very insignificant. The tertiary plants of Œningen have indeed yielded a rich harvest of fragments to Prof. Heer; those of Madeira have been fortunately collected in some quantity and submitted to this palæontologist, and also to our own Bunbury, whose careful examination of them has just appeared in our Journal ||. Materials for the Tertiary Flora of Europe gradually accumulate; and I may call attention to two of the latest and most interesting of these efforts in this direction—one relating to the brown-coal deposit of the Lower Rhine; the other to the beds of the Val d'Arno, 200 feet below the remains of *Elephas antiquus* and *Rhinoceros leptorhinus*. In this latter repository, and in some other localities in Tuscany, Count Strozzi has for some time been engaged in mining for plants. The result of his labours in the Val d'Arno is the discovery of fifty-nine species of plants, belonging to thirty-six genera, mostly now living in the neighbouring countries; Amentaceous plants and Juglandaceæ are in large proportion. Of the species, twenty-one, marked as new, are mentioned only as Tuscan. Of the thirty-eight which were known before, twenty-three are found at Œningen or Locle, in Switzerland, and eleven at Schossnitz. The conclusion adopted by M. C. T. Gaudin ¶ is, that this Tuscan fossil flora forms the link between the beds of Œningen and those carbonaceous beds of Utznach and Durnten which contain the *Elephas antiquus* and *Rhinoceros leptorhinus*. Several of these species appear again in the beds of Sanganello, in Piedmont (supposed to be Upper Miocene);

* Geol. Proc. Jan. 5, 1859. † Quart. Journ. Geol. Soc. vol. xv. p. 76.
‡ Ibid. p. 80. § Ibid. p. 50. || Vol. xv. p. 50.
¶ Bulletin de la Soc. Vaud. vol. vi. p. 43, 1858.

and three are common to Tuscany, Piedmont, and Œningen (*Platanus aceroides*, *Carpinus pyramidalis*, and *Laurus princeps*).

Of much later date than these are the plants collected from the prehistoric tufas of Somma, all of species living in the vicinity, according to Gaudin, who also mentions among the fossil plants of Lipari Palms, *Smilax*, *Quercus*, *Laurus*, and *Aristolochia*.

The labours of Wessel and Weber and earlier observers on the flora of the brown-coal of the Lower Rhine have yielded 237 distinct forms, of which 94 have been found at Œningen and other localities, but 143 as yet only in the Brown-coal. The plants described include 5 Ferns, 3 Palms, 21 Conifers, 15 Quercus, 13 Laurineæ, 7 Proteaceæ, 9 Acer, 7 Juglans, 18 Leguminosæ,—a singular assemblage, as Mr. Bunbury remarks; for the Proteaceæ are now living in South Africa and Australia, countries entirely destitute of Cupuliferæ, which are so largely represented in this flora, and in other regions of north latitude*.

It were much to be desired that the processes of mining should be resorted to in the Oolitic shales of England, as at Gristhorpe and Cloughton, and many other places in Yorkshire, and in the tertiary shales at Bournemouth, Studland, and other points in the South of England, where sufficient traces occur of stems, leaves, and fruits of plants, to encourage the hope of important results.

### *Zoology.*

There is no ground for fear that the study of the perished forms of animal life should ever lose its hold on the serious attention of geologists. To make this study available in so difficult a matter, demands, however, somewhat more than a slight acquaintance with Zoology. No great success can be expected in Palæontology by him who is not to some considerable degree trained in Comparative Anatomy and Physiology. Very slight and trifling, if not mischievous, is that minute industry which, unguided by philosophical reflection, busies itself only with differentials of specimens, and abandons the true integration of species, the work of the real naturalist. On this account, the conscientious labours of Davidson on Brachiopoda and of Wright on Echinodermata, which are among the later works of the Palæontographical Society, are to be mentioned with honour; so also must we listen with respect to the profound reflections of Owen, addressed to the British Association at Leeds; and to the voice which, though coming from the Transatlantic world, brings to Europe the wholesome influence of Agassiz, who first opened to us a road among the confused assemblages of unknown fossil fishes.

Not intending in this Address to make Palæontology a prominent object, I shall merely refer to the additions made by Dr. Kinahan to our knowledge of Oldhamia, Mr. Wetherell's notice of Graphularian nodules in the London Clay and the Crag, Mr. Bates's description of a small Crustacean from the Magnesian Limestone of Durham, Mr. C. Gould's new Crustacean from Atherfield, Mr. Salter's

* Bunbury, Quart. Journ. Geol. Soc. vol. xv. 1859.

notice of Eurypterus, Mr. Leckenby's additions to the Fauna Calloviensis of Yorkshire, Mr. S. Wood's Extraneous Fossils of the Red Crag, Messrs. Brown and Sowerby's Tertiary Fossils from Chislet, Mr. Stow's Fossils from South Africa, Prof. Owen's account of the Zygomaturus and Nototherium, and of the Marsupial Lion of Australia, and Dr. Bigsby's remarkable analytical tables of the palæozoic fossils of North America. But one investigation claims at least a few words, if only to express our thankfulness for the liberal and prompt aid given by the Government Grant Committee of the Royal Society to the exploration of Brixham Cave, suggested by Dr. Falconer, in which bones of Mammalia occur, and also flints apparently fashioned by human art.

Nothing can be more interesting, perhaps nothing more difficult, than to collate the scale of historical time with that of the latest geological period, in the very limited portion of this period which can be safely admitted as coeval with the race of man.

*Brixham Cave.*

The excavations already made by aid of two grants from the Royal Society, and some private contributions, have proved this cave to be in essential points similar to many others known and explored in the same and in other parts of the British Isles. The calcareous rock is divided by joints, in two sets crossing at right angles, north and south and east and west. These joints have been in many cases enlarged by the percolation of rain-water, and perhaps, at an earlier period, by drainage-currents or the sea-waves, when the land was at a lower level, as it is known by several cases of beaches to have been, all round the coasts of Devon and Cornwall. On the floor of many such caves is often a coarse, more or less pebbly, deposit; over this a loamy deposit, sometimes containing bones of Mammalia. Some more limited deposits lie on this loam, and in parts the whole is sealed down by stalagmite. Human remains occur sometimes under, but elsewhere above, the stalagmite.

The conformity of the cave at Brixham to what may be called the normal formula is of much importance; for if, by the steady prosecution of the works, the probable history of the cave can be satisfactorily recovered, the light thus kindled will spread through many caverns which have yielded a larger variety of bones to less attentive observers of the circumstances which accompanied them.

An admirable map and exact sections of the windings of Brixham Cave have been prepared by Mr. Bristow, who adds to this valuable contribution a well-digested memoir of his personal observations. The excavation is under the care of a diligent committee, the specimens are to be forwarded to London, and Dr. Falconer, who is expected home in the spring, is charged with the task of describing the mammalian remains.

If it be asked what useful purpose may be served by all this labour of preparing maps and sections, and determining the affinities of fossil plants and animals, we may reply, that in no conditions of society is the comfort and convenience of mankind independent of a knowledge of natural products.

——— e terra quoniam sunt cuncta creata.

And, though certainly necessity and long experience have led to the slow discovery of many practical rules which geology has now exalted into scientific truths, still on very many subjects of importance practice is silent when geology foresees. Thirty years ago it fell to the lot of your President to publish on maps, and to explain in sections, the position of certain ironstone-bands in the Oolitic series of Yorkshire, and yet only a few years since they came into work, though now they yield 1,800,000 tons per annum, and pay to the landowners of that region rents probably amounting to £60,000 per annum. In a recent experiment for coal, near Worksop, on the estate of the Duke of Newcastle, which I rejoice to hear is successful, the trial is made some miles from any existing colliery, and the shaft is sunk through strata which were not only devoid of coal, but, until geology taught better things, were not believed by practical men to cover coal at all.

*Iron-ores.*

The earliest notice of the iron-works of Britain is in the Commentaries of its earliest Roman invader. According to Cæsar*, iron rings of a certain weight were in use, as well as brass, for money: in small quantity, iron was found in the maritime parts, by which we may understand Sussex. In a somewhat later Roman age the Forest of Dean was full of small iron-forges, among the scoriæ of which lie fibulæ, images, and coins of Trajan and later emperors. In the midst of primeval forests, the principal iron-works of England flourished till the middle of the 18th century; traces survived in the great wood of Andredesweald till within our own days; nor are they yet extinct in the Forest of Dean, and by the shore of Windermere. The iron trade of Sussex moved to South Wales, allured by the abundance of iron-ore, accompanied by still greater abundance of mineral fuel, which by coking became effective in smelting argillaceous carbonates of iron. The same causes carried the iron trade into almost every coal-tract of England, Scotland, and Ireland, till it became a settled maxim, that for the profitable exercise of the art of smelting iron, the iron-ore and the coal must be adjacent. Lately, however, a new aspect has been given to this important trade by the extension of railways in England, which have rendered it possible to bring into employment the ores of iron which occur in the Oolitic strata. These are plentiful in particular tracts; they occur, as far south as Weymouth, below the Kimmeridge clay; but more abundantly, in Oxfordshire, Northamptonshire, and Lincolnshire, immediately above the Upper Lias clays; and in most of these counties, as well as Rutland, in the midst of the Lias, above and in the Marlstone.

* Utuntur aut ære, aut annulis ferreis, ad certum pondus examinatis, pro nummo. Nascitur ibi plumbum album in mediterraneis regionibus, in maritimis ferrum; sed ejus exigua est copia: ære utuntur importato.—*De Bello Gallico*, v. 12.

But nowhere is the quantity so great, the variety so remarkable, the richness carried to such a height, as in the eastern moorlands of Yorkshire, where in and above the Lias are at least thirteen noticeable bands of iron-ore, more than one of them yielding above 40 per cent. of iron (in selected examples 50), two of them so thick and so purely ferruginous as to yield, one from 20,000 to 50,000 tons per acre, the other from 10,000 to 100,000 tons. This last, in its best state, near Rosedale Abbey, is magnetic with polarity, and purely oolitic, with scarcely any earthy impurity, and hardly a shell, or coral or crinoid, or fossil of any sort in its dark blue mass, 32 feet in thickness. It lies at the very base of the Oolitic formation,—upon the top of the Lias.

On reviewing the circumstances under which these great stratified deposits of iron-ore are found, we observe that, in general, they appear in the parts of the strata which geographically approached the ancient shores,—they are even most abundant in the freshwater portions of the deposits—as, *e.g.* in the Weald of Sussex, at Seend in Wiltshire, in Shotover-hill, in the Moorlands of Yorkshire. The mechanical origin of the deposits by drifting is thus put in evidence. The occurrence of plants, and even coal-beds, in these same tracts, is easily seen to be probable, and it is the fact, though the carbonaceous deposits are of small value.

In the view of Prof. W. B. Rogers this association of the carbonaceous element with argillaceous iron-ore is necessary—the iron appearing as it does in consequence of the action, on minerals which contain it, of the carbonic acid which is generated by the decay of the vegetable masses. The magnetic ironstone of Rosedale seems to suggest a view of the same kind, without the necessity of supposing the actual state of the oxide of iron to have been accomplished by changes on the spot.

Let us imagine a silicate of peroxide of iron (as augite), in a state of decomposition, to which the reducing agency of free carbonic acid and water should be applied while nascent from decomposing animal or vegetable matter. The result might be a mixture of peroxide and protocarbonate of iron with silica, carbonate of lime, and some other less essential matters. It is probably to this composition, partly peroxide and partly protoxidated iron, that the magnetic quality of the ore is due. I am happy to say that Mr. Sorby is still engaged in those ingenious researches into pseudomorphism which have already enabled him to exhibit the substitution of carbonate of iron for carbonate of lime, without change of form or crystalline structure.

Not to speak at present of the rich ores of iron which occur in the west of Somerset* and north of Devon†, or of the magnetic ore which occurs in the veins of Snowdonia, I may add a few words on the very rich and abundant deposits of red peroxide which lie in the limestone tracts of West Cumberland and North Lancashire. Partially stratified, covered by limited stratification, and resting on limestone, these

* From information communicated by Sir Walter Trevelyan.

† Professor W. W. Smyth on the Iron-ores of Exmoor, Quart. Journ. Geol. Soc. vol. xv. p. 105.

deposits have been regarded as beds in the calcareous series. But, as the works run in lines, as the boundary, on one side at least, is often a fault, and the vertical depth is often enormous, the analogy to veins and dykes is not less obvious. I find, by a recent personal survey, that the deposits often lie in hollows which have been excavated in the limestone, that they often suddenly terminate against a subterranean cliff of limestone, and colour the rock, but are never really interstratified with it. Thus their age is certainly later than that of the limestone, and later than that of the faults which there divide the limestone. These faults are probably anterior to the Permian system; and, as some beds probably of the New Red deposits lie, though rarely, over the iron-bands of West Cumberland, there seems good reason to fix these hæmatitic iron-ores as a deposit of the Permian age, transported in water free from coarse sediments, accumulated in hollows of the calcareous sea-bed, in water of some considerable depth, and at some considerable distance from coast- and river-currents*.

*Gold-fields of Australia, Vancouver's Island, &c.*

In every age and in every country the history of gold-working is the same. Rivers with golden sand, alluvial sediments, the gift of earlier streams, detrital accumulations gathered in hollows, not far from the parent rocks and veins, yielded gold to the treasury of Rome, as now similar deposits, washed in nearly similar modes, fill the exchanges and manufactories of Europe†. Several interesting memoirs on the Australian gold-fields have been communicated to the Geological Society. The papers of Selwyn and Rosales and others may be quoted as affording a remarkable proof of the scientific spirit which now at least is present, if it can hardly be expected to prevail, among the hardy adventurers in a new world of discovery, where gold exists, in masses weighed not by pounds, but by hundreds of pounds. Some of the points clearly established by their researches have been brought before us by Messrs. Phillips and Rosales, and illustrated by maps and sections. To a map showing the actual drainage in the gold-district of Ballaarat and Mount Alexander, there has been added, by the progress of heavy toil and deep digging, another older and deeper system (and perhaps more than one) of auriferous drainage, having different stems and different branches.

This old drainage, ramifying like any actual streams, and collecting like them into main channels, takes a course towards and under a great plateau of trap-rock, the fruit of volcanos which still are represented by a few craters elevated in this region.

And, below this basaltic plateau, lies in places a bed of dark carbonaceous clay, containing remains of plants like those now living in the country, and living in no other continent, especially of the

* Prof. Phillips and Mr. Barker on Iron-ores of West Cumberland and N. Lancashire, in Brit. Assoc. Report, 1858.

† The Rhine sediments still yield gold, mostly in thin scales, lying among quartzite and other pebbles, often under but not in the loess. Its probable origin is in the quartzites, traps, and schists of the Alps and other ranges yielding water to the Rhine. (Daubrée, 'Constitution du Bas-Rhin.' 1852.)

genus *Banksia*. In places also tree-stems of great magnitude stand erect on the rocks below this great old lava-flow, enter it upwards, and are embraced by it, and partly mineralized within it. In some future day the deep workings may penetrate under the capping of basalt, and disclose new wonders preserved under this rocky wax, which nature freely uses in sealing down the memorials of earlier time.

*Geological Theory.*

Side by side with the numerous—I had almost said the innumerable—data which have been collected for geological inference, the masters of mechanical, chemical, and physiological science are silently establishing, though in a fragmentary state, those special laws of causation, by which, if at all, we are to combine our data into general theory.

If no new force be added to the system of nature, neither has any old force died away. Natural forces may, indeed, be gathered into treasure-houses, and reserved, as in a seed, to germinate another day; but, like the moral forces which sway mankind, they are not permitted to die, though they may appear to sleep.

The force which moulded our planet into its spheroidal form still exists to maintain equilibrium in its rotating mass*, the products of chemical affinity are the same to-day as in the earlier ages of the world, under the same circumstances; but as these circumstances—that is to say, the combinations of natural conditions—alter, so the effects of mechanical and chemical agencies are measured by standards which vary with time. In a still greater degree is this found to be true when we think of the phænomena of life, which are made to depend on mechanical and chemical quantities, and to vary in some proportion to the changes of these.

In what direction and to what degree are the general physical or mechanical conditions of the globe subject to variations? By what results are such variations followed?

That the mean *dimensions* of the globe are not subject to notable changes, seems evident by the experience of 3300 years; for during that period of time, the relative length of the year and the day, as determined by Hipparchus, has remained sensibly the same, which probably would not have been the case if the unchanging velocity of rotation had been operative on a variable mean diameter†.

* Sir John Herschel has indeed suggested, and it may be readily admitted, that the earth, if constructed originally a sphere, and then set to rotate, would, by the action of surface-agencies, change its figure and become spheroidal; but he has not attempted to show that the actual ellipticity would be so acquired ('Astronomy,' chap. iii.). Professor Hennessy concludes that, on the supposition of the external figure of the earth being due to the abrading action of water at the surface, the compression should be $\frac{1}{404}$, and not, as it is, about $\frac{1}{300}$, this latter fraction agreeing with the hypothesis of primitive fluidity (Mem. Roy. Irish Acad.; and Brit. Assoc. Report, 1852).

† It appears that approximate constancy in the length of the day is not inconsistent with the admission of a real diminution of diameter; for its effect might be counteracted by a change in the law of density of the fluid nucleus. (Hennessy "On the Earth's Internal Structure in relation to the Length of the Day," Phil. Mag., 1856.)

That the general *form* of the globe has been almost equally constant during all the reach of history, is established, at least for those countries which have a history.

The boundary of land and sea may be somewhat altered locally, by the growth of new land from the detritus brought by rivers, or by local elevations, whether traceable to earthquakes, or to the general "reaction of the interior of a planet on its surface*;" but there is no evidence of any general gathering of waters round the poles, or of recession from them, in historic times, as must have happened if the ratio of the equatorial and polar diameters had changed or were changing†.

Geologists are far removed from the centre of the earth, yet they sometimes indulge in language which implies no small familiarity with the region immediately surrounding it. The interior fluid nucleus of the globe, the waves on the surface of this liquid, the shrinking of this fiery globe within its warmed but solid crust‡, the consequent production of chasms and volcanos of elevation, of alternate mountains and vales, the injection of igneous rocks, the metamorphism of strata, the changes of surface temperature, the displacement of land and sea, the destruction of old systems of life, and the preparation for newer and more advanced races of plants and animals —these and more than these physical and geological phænomena, are they not freely and confidently spoken of as necessary corollaries from the admission of the planet having been once fluid through

* Humboldt uses this expression in his great work 'Kosmos.'

† The periodicity of deluges—an idea frequently recurring in geological speculation—has been made the subject of a treatise by M. LeHon. The well-known facts that the winter and summer halves of the earth's orbit are of unequal length, and that, by the displacement of the apsides of the earth's orbit, this inequality is periodic, and visits the poles alternately, were considered physically by Herr Adhemar ('Die Revolution des Meeres,' Leipzig, 1843). This mathematician conceived that he had found in the inequality of mean annual temperature occasioned by the inequality of the half-yearly periods, a cause for vast accumulation of snows and thickening of glaciers, first round one pole, and afterwards, on the change of the cycle, round the other; while at some point of time during the change from one condition to the other, there would be a vast and general thaw, occasioning enormous floods, and a readjustment of the earth's centre of gravity to its new centre of figure. The astronomical data may be thus stated:—

| | ″ |
|---|---|
| Precessional motion in arc, per annum ............... | 50·1 |
| Motion of apsides in opposite direction ............... | 11·8 |
| | 61·9 |

∴ Tropical period (when apsides return to equinox) =

$$\frac{360^\circ \times 60' \times 60''}{61{\cdot}9} = 21{,}000 \pm \text{ years.}$$

‡ This, the usual form of the hypothesis, is controverted by Hennessy, who (Report of Brit. Assoc. 1856) suggests the elevatory pressure exerted by the more oblate fluid nucleus against the solid crust as more favourable to symmetrical fracture than would be a general downward pressure and collapse, according to the views of De Beaumont, the author by whom the systems of fracture in the earth's crust have been most fully examined. The thickness of the earth's crust, inferred by Hopkins to be about one-fourth of the radius, is reduced by Hennessy to a maximum of 600 miles. These authors agree in finding the axis of the earth to be nearly immoveable, and the mean inclination of this axis to the plane of the ecliptic to be also permanent.

heat, and still preserving its "chaleur d'origine" under the crust of rocks which has cooled and crystallized to some depth from the surface, and the sheets of earthy sediment deposited beneath the waters which that cooling allowed to be collected? Is this fundamental assumption true? and, if true, are these consequences fairly derivable from it? Is the globe passing through a series of conditions which never can be repeated, a series having a clear trace of a beginning, a sure prospect of an end?

Towards the settling of these questions geology contributes somewhat, physical research something more. The earth is hot within; this heat flows to the surface in a feeble stream, and augments the temperature there by a small fraction of a degree. The temperature at the surface is thus constituted by radiation from the sun and heavenly bodies, added to that received by conduction and convection from the interior of the earth, and diminished by the radiation into the starry spaces around. These spaces are very cold; and the earth is losing continually a little of its warmth. It is growing colder in its whole mass—slowly indeed, so slowly that the effect has hardly been felt by any change at the surface during all the reach of history, but surely, regularly, and continually; and this has been the case during all prehistoric periods, while our solar system has been guided along its cold ethereal path. The further back we go in this contemplation the warmer grows the surface, the greater the flow of heat outwards; the nearer to the surface any given isothermal line, the smaller the depth at which we should reach the heat of boiling water, of sublimated gases, of fused rocks and metals. As the internal heat certainly, if slightly, now influences and exalts the temperature of the surface, it must formerly have influenced and exalted it more.

*But how much more?* Can we ascribe to this cause the once elevated temperature of the north temperate and even circumpolar zones of the earth, which seems to be indicated by the cycadaceous plants, the palms, and the tree-ferns, no less than by the coral-reefs and the crocodilian, enaliosaurian, and deinosaurian reptiles of those latitudes in all but the most recent geological periods? Let us suppose that for these effects a general augmentation of 10° to the temperature in the northern regions might have sufficed in the older periods, the present augmentation of temperature by flow of heat from the interior being $\frac{1}{20}°$; if the flow of heat depended only on conduction from particle to particle, and bed to bed, it must have been 200 times greater, in a given time, in the early period than at present, and the augmentation of temperature in descending must have been 200 times greater in a given vertical space. Therefore the temperature of boiling water, now perhaps attainable at about 10,000 feet, would, under this limitation, have been found at $\frac{10000}{200}=50$ feet, and all but surface-springs would have been springs of boiling water*.

* If $f$ denote the excess of the present surface-temperature above the final limit to which the temperature would descend in an indefinite period of time, and $g$ the rate of increase of temperature, we have $\frac{f}{g}=b$, where $b$ is nearly equal to unity.—*Hopkins, Address to the Geol. Soc.* 1852.

Such a state appears hardly reconcileable with the existence of the trees and other land-plants which abounded in the Carboniferous period; and the time which must have since elapsed in cooling down to the extent of 10° is only to be expressed in almost countless millions of years, while some of the phænomena to be explained belong to the latest or tertiary periods of geology.

As long as our reasonings on this subject are limited by the condition of constancy in the mass and quality of the atmosphere, and in the influence of the sun and ethereal spaces, these objections apply; but if, further, we consider what must be the effect of an augmented surface-heat on the ocean and the atmosphere, we shall see reason to modify this opinion. The oceans, especially deep oceans, would distribute a largely augmented measure of circulating hot water, as well as throw off more aqueous vapour. The winds would be more powerful, and have a greater effect on the ocean-streams, to which always, and in all conditions of the globe, much of the peculiarity of local climate beyond the tropics is due. The larger volume of aqueous vapour transferred to the atmosphere in one region would give out, on condensation in another, a larger measure of heat*, and it is conceivable, that with such an atmosphere, operating like extra packing round a steam-pipe, the waste of heat by radiation from the surface of the earth might be reduced. From these causes the surface-warming effect of a given determinate flow of heat to the surface of the earth might have been in a higher ratio than that indicated by the intervals of the isothermal surfaces.

Nor is this the only, or even the principal, argument which may be urged in mitigation of the strict interpretation of the formula. It is manifestly altogether dependent on the identity of the atmospheres, not only as to the weight of the vaporous element, but still more on the mass of the gaseous elements. Who is to assure us that the constitution of the atmosphere, which is not a chemical compound, but an aërial mixture, is necessarily fixed and constant? Is it not, on the contrary, most probable that it is variable, both in the proportions of oxygen, nitrogen, and carbonic acid, and in the sum of the whole? What is it but the gaseous residuum of a planet cooled and solidified, but still for half its weight composed of oxygen capable of emancipation by augmentation of heat and reduction of pressure? Is not a good part of the history of rocks the history of chemical changes, often characterized by the absorption and condensation of oxygen-gas? Has not the atmosphere lost sensibly of its ancient proportion of carbonic acid, now fixed abundantly in coal, and still more in limestone? Could we now increase the mass of the atmosphere by only a small fraction, would not the temperature at the earth's surface be sensibly augmented, and the waste of heat by radiation diminished?

These considerations appear to me to have weight; and if the idea of a diminishing atmosphere and a decreasing ocean be unfamiliar, it may perhaps be more readily grasped if we scrutinize the dry sur-

* The weight of vapour which air is capable of taking up is doubled by an elevation of 21° Fahr.

face of the moon, and during the passage of this luminary over the stars watch in vain for the signs of an atmosphere. Yet the moon has been partly covered by water in ancient times, as the undulated plains, the dry deltas, the dry seas on her surface appear to prove; she has had an oxygenous atmosphere, if we may judge by the lava-streams and monticules, with small craters, as well as the greater mountains, which seem to tell of explosive vapours, and the oxidation of minerals and rocks. If her atmospheric life be ended, and she now fluctuates between great heat and violent cold, what is to assure us that the earth, whose physical history is bound up in so many ways with that of her brilliant companion, has not experienced in a lesser degree the effects of similar vicissitudes?*

The flow of heat and cold in the crust of the earth is accomplished partly by *conduction* from particle to particle in a given rock, and from one mass of rock to another, across the divisional surfaces of joints and beds; and partly by *convection* through the agency of water and air. An experimental investigation lately undertaken by Mr. Hopkins† shows that the conducting power of the rocky crust of the earth varies much, while the rate of increase of heat as we go downwards is more nearly uniform. The conducting powers of different substances tried, as *dry powder, dry solid,* and *moist solid,* were thus found:—

| | Dry powder. | Dry solid. | Moist solid. |
|---|---|---|---|
| Chalk | ·056 | ·170 | ·300 |
| Clay | ·070 | ·230 | ·370 |
| Sand | ·150 (New Red) | ·250 (New Red) | ·600 |
| Freestone | — | ·330 | ·450 |
| Sand and clay | ·110 | — | — |
| Ancaster oolite | — | ·30 | ·40 |
| Hard compact limestone | | ·50 | ·55 |
| Millstone-grit | — | ·51 | ·76 |
| Hard Palæozoic sedimentary rock | | ·50 | ·61 |
| Igneous rock | — | ·53 | ·100 |

Now, as artesian wells sunk in chalk, triassic, and carboniferous strata yield water whose temperature exceeds that of the surface by about 1° from 45 to 60‡ feet, and as these are about the limits of the ratio of increase given by experiments in the solid rock—it appears that the range of conductivity of the rocks is twice and a half as great as the range of the observed ratio of increase of tempera-

* Geologists may be reminded that the figure of the moon is not like that of the earth. She has been conjectured to be a slightly prolate spheroid, with the polar axis, which is directed to the earth, 186 feet (see MacLaurin's 'Newton') longer than the equatorial diameter. Nor is her centre of gravity coincident with her centre of figure (according to Hansen), but excentrical, 33½ miles further from the earth, on the polar axis.

† Roy. Soc. Proc. 1857, and Trans. 1857, p. 805.

‡ Mr. Hopkins selects six examples to show the comparative uniformity of the law of increase of temperature and depth, varying from 54 feet to 65 feet for 1° Fahr. But the limits are really much wider, from less than 30 feet to more than 60 feet in the mines of Cornwall alone.

ture in these rocks. Therefore the rate of augmentation of temperature as we descend cannot be fully explained by *conduction.*

As the whole crust of the earth is traversed by innumerable fissures, which admit of vertical and horizontal movements of water and air, it is manifest that these currents must be, in a majority of cases, more effective to considerable depths than the mere flow of heat-waves through solid rock. Side by side, the granite and slate of the Cornish mines are of unequal temperatures, and both differ in this respect from the cross-courses and veins*.

The distribution of water in the cavities of the rocks may be conceived to influence their temperature in three ways. Let us suppose a case like that of the artesian wells of London, where water is pumped up in great quantity from subterranean reservoirs, which it has reached by continually *descending* from the hills of Surrey and Herts. In this case the water is warmed by the subterranean rock, which therefore it cools, as far as the current extends, and the final temperature of the issuing water is *less* than that of the isothermal due to conduction (*a*). But suppose no artesian well in this locality, and *no great current* of water depending on gravitation, but only a very slow circulation of water through all the fissures, and of heat with it, the flow of heat outwards would in this case be only a little greater than by mere conduction (*b*). Lastly, suppose a case like that of some of the Cornish mines where the water descends from the surface along veins highly inclined, and attains depths much greater than those reached by the miner, to receive heat also greater than that due to the depth at which the spring is cut by the miner, and made the subject of thermometrical experiment by the philosopher (*c*). In these cases, other things being the same, *the rate of increase* of temperature for a given measure of descent would be different—least at *a*—greatest at *c*. If we assume *b* as a mean, and take averages of *a* and *c* for the extremes, we shall have nearly these numbers,—

*a*. 60 feet,
*b*. 50 ,,
*c*. 40 ,,

Now, by Mr. Hopkins's Table of *conducting* powers already given, the ratio for *a*, artesian well in chalk, being 1° for 60 feet, that for *c* (as is seen in granite or slate) should have been about 1° for $60 \times 2{\cdot}5 = 150$ feet. To augment the temperature to what it is in the Cornish mines, we must increase the fraction $\frac{1}{150}$ by $\frac{11}{600}$, the heat communicated by convection, which, in this case, is twice and three-quarters as great as that obtained by conduction.

The important thermal influence of water circulating through the Cornish mines is recognized by Mr. Henwood†, whose observations were made by preference on the springs rather than the rocks. He remarks that at equal depths the cross courses are colder than the

* Henwood on the Metalliferous Deposits of Cornwall and Devon.

† Henwood on Subterranean Heat in Cornish Mines (Trans. Roy. Geol. Soc. Cornwall, vol. v.).

lodes, and these are not so warm as the rocks. Now the cross veins appear to carry downward the *largest* quantity of rain-water. Tin-veins are colder than copper-veins. Granite is very sensibly colder than slate: at 240 fathoms, one is recorded 76·15°, the other 89·4°. From the surface to 150 fathoms the rise of temperature seems to follow a ratio diminishing downwards, but from that point it augments again.

The latest experiments by Mr. Fox bring out the same variations in regard to the rocks and lodes, and the influence of water-streams on the observed temperature. His experiments were made in the solid. They show six cases in granite, which give a ratio of 54, 63·7, 48·4, 71, 55·3, 52·1, mean 1° in 57·4 feet, and five in killas, 32, 39, 36·7, 41·3, 43·7, mean 1° in 38·5 feet*. If waste of heat depending on soil may be thought to be constant, isothermals under these rocks would be suddenly bent upwards in the killas, the flexure being greatest in the greatest depths.

Now, as granite is the better conductor for heat, it would seem that here we may recognize the fact that conduction retains a sensible share of communicating heat upwards, thus confirming the view that this heat augments regularly downwards to a considerable depth.

The highest temperature recorded in the Cornish mines is 116° (the temperature of the hot spring at Bath). It occurs in a warm spring in United Mines at 255 fathoms, giving 1° for 23·2 feet. At the same depth *in rock* in another level of the same mine the temperature is such as to give a ratio of 1° in 47·0. Here we have unequivocally the evidence of the warming agency of the water circulating in the mining-district of Cornwall. The temperature of 116° may be conceived to arise from a depth of 2200 or 2300 feet—or 800 feet below the floor of the mine.

The surface of the earth is, in fact, now more heated by convection of heat up its cracks and fissures than by conduction through its solid masses. In earlier geological times these cracks and fissures were undoubtedly more open than now: for many reasons it is conceivable that the circulation of water was both more abundant and more rapid; and thus, exactly as our greenhouses are warmed by hot-water pipes, it is supposable that the ancient earth-surface was warmed by currents along the innumerable void spaces now in part filled by the sparry and mineral matter left by those very waters, which have thus contracted or obliterated their own channels, but have left monuments not to be neglected in reasoning on the ancient condition of the earth.

Once clearly in possession of this view of the pervading action of water heated by the rocks which it traverses, and of the considerable depths which it reaches in countries far from volcanos, and the great depths to which it penetrates in those countries, we turn with interest to these inquiries of modern times which have disclosed the chemical results attainable by water under such conditions.

From careful personal inspection, Bunsen arrives at the conclusion that none of the rocks of Iceland are capable of resisting the action

* Fox, in Report of British Association, 1857.

of the hot water. This agent of perpetual change breaks up the pelagonites, clinkstones, trachytes, traps, and lavas ; by liquid flowing, or steam condensing, it removes the separated parts, dissolving some, depositing others, and giving rise to continual new earthy combinations, diversified by sulphates and sulphurets.

Professor Daubrée, of Strasburg, one of that distinguished band of Frenchmen who combine the experience of the engineer with the skill of a chemist and the zeal of a geologist, has shown how the natural action of the warm springs flowing from the Vosges Mountains has generated zeolitic and other minerals, differing in their nature according to the materials which they traverse. The waters of Plombières, issuing from the granitic region, and specially from veins in it, which yield fluor-spar and quartz, with a temperature not exceeding 73° C. (163·4 F.), hold silicates (chiefly of potash) and fluorides in solution. These waters, acting on the varied mass of bricks, cement, and mortar, which make the cement employed in the old Roman bath-channels at Plombières, have penetrated the mass, and generated in the cavities apophyllite, chabasite, and other zeolitic minerals—opal, arragonite, calc-spar, fluor-spar, hydrocarbonate of magnesia, &c. Not that all the materials of these minerals have been brought by the water and deposited by it, for the material traversed has contributed its effect, and has undergone transformation. Apophyllite, a silicate of lime, is found in the mortar, and not in the brick; while chabasite, a double silicate of alumina and potassa, is found only in the brick.

These remarkable results suggested to the author a great and evident analogy to the exhibition of zeolites in rocks of the eruptive igneous class. Basalts and amygdaloids often contain zeolitic minerals, which have been formed in cavities subsequently to the first consolidation of the rock, so that examples might be chosen from the more porous varieties hardly distinguishable from the metamorphic concrete of Plombières. This identity of results demands the admission of a similar origin. With higher temperatures than that of the Vosgian springs, and under higher pressures, it is conceivable that a still larger range of mineral aggregates, even anhydrous silicates, might be displaced and replaced; and thus, for the filling of some mineral veins and many metamorphic phænomena, not heat, but heated solutions, would appear to be agencies both real and sufficient.* The same author has, however, shown us the production of oxide of tin and quartz, by sublimation of fluorides, in presence of aqueous vapour, and other facts bearing on the production of sulphurets and silicates by heat alone †.

Volatile fluorides, according to Ste.-Claire Deville, acting on vapour of water and oxygenized compounds, occasion mutual decomposition and exchange of elements. Thus, for example, volatile fluoride of aluminium, acting on boracic acid, occasions the produc-

* 'Mémoire sur la Relation des Sources Thermales de Plombières,' &c. (Ann. des Mines, 1858).

† 'Sur la production artificielle de quelques espèces minerales' (Ann. des Mines, 1850).

tion of oxide of aluminium (Corundum) and fluoride of boron. Similarly ruby, sapphire, staurotide, and other aluminous minerals have been produced; and it is conceivable that this kind of action by sublimation may have had influence in the filling of mineral veins.*

If carbonate of lime be soaked in chloride of magnesium, and exposed to a moderate heat (100°–200° C.), the salts are partially decomposed, and a part of the lime is replaced by magnesia. If the chloride of calcium which is formed in the process be removed, and fresh chloride of magnesium be added, a second dose of magnesia replaces a second part of the lime, and forms dolomite. Sulphate of magnesia will have an analogous effect. If clay and chloride of sodium be employed instead of carbonate of lime and chloride of magnesium, a silicate of soda may result; and by varying the process, other proofs may be gathered of the generation of minerals under aqueous action heightened by heat.

The ingenious researches of M. Alphonse Gages, who by means of partial solution of several minerals has shown them to be compounds in which metamorphosis has been partially carried out, so that a skeleton of one mineral lies concealed in the substance of another†, appear to deserve the special attention of mineralogists, who by means of the modern microscope and polarized light have at their command powers of investigation unknown to Werner and Jameson, De L'Isle and Haüy, Cronstedt and Linnæus, and only partially employed by Mohs and Naumann and the great writers of Germany.

The labours of M. Delesse on the great subject of the metamorphism of rocks have already drawn forth the praises of my predecessor, himself one of the earliest and ablest of the inquirers into the changes which the elder strata of the earth have experienced by the action of known and probable causes‡. The recent publication, in a complete form, of the series of researches for which we are indebted to M. Delesse, has placed in the hands of geologists a summary at once clear, full, and precise, of the principal facts which have been recorded by eye-witnesses of the apparent effect of granitic and doleritic masses, dykes, and veins, on strata of various kinds in contact with them—carbonaceous, calcareous, arenaceous, argillaceous, ferruginous. The numerous examples of this local metamor-

* Geologist, Nov. 1858. Dr. Phipson's communications to this publication furnish many valuable and interesting notions of the progress of Continental geology.

† Thus in the fibrous dolomite of Miask (Ural) an asbestiform skeleton of magnesian tremolite may be detached by means of diluted hydrochloric acid; and in the magnesite which borders a dyke of trap where it passes through chalk, near Maghera, the same process discloses a skeleton of pure silica lighter than water. Serpentine cut in thin slices, and treated with acid, discloses the substances of which it is composed, leaving always, however, a siliceous skeleton—an evidence of its metamorphic origin. (Communications to the Geol. Soc. of Dublin and the Brit. Assoc. 1858.)

‡ The chapter on Igneous and Metamorphic Rocks which enriches the Report of General Portlock, on Londonderry, Tyrone, and Fermanagh, could have been written in no other country than Ireland, and by no other hand than that of our late President. Dated in 1843, it is full of facts and ideas of the highest geological interest, the fruit of many years of reflection and research.

phism, taken from the British Islands, and often described from personal inspection, render this volume indispensable to those who desire to follow out the useful teachings of Macculloch, or to consider with attention the theoretical views of Hutton and Lyell.

Distinguishing in the first place between the case of "normal metamorphism," operated on a vast scale, and by the means of a general pervading agency, in which heat, if not the sole cause, is the great excitant, M. Delesse determines, in some specially favourable cases, the probable temperature to which strata have been exposed through contact with heated plutonic rocks. It is well known that the effects on carbonaceous rocks which have been submitted to this metamorphism by contact are the loss of volatile parts and the production of coke—often in prismatic forms as regular as that of consolidated lava. The temperature necessary for these effects is found to be lower than that often assumed by geologists for the effects of this order, and not to exceed 400° C.=under 800° F., somewhat below red heat. Supposing the increment of temperature to be 1° C. for 33 metres, this heat would be met with at 13,200 metres, say 40,000 feet. It does not appear to M. Delesse that the effect of metamorphism by heat is much modified by mere depth, for the changes effected by subterranean fire, when they can be accurately noted, confirm this; and, by consequence, rocks which have been really submitted to intense heat have always a certain character stamped on them by which they can be recognized. Thus the study of metamorphism by contact embraces two branches—the changes in the rock which encloses the once fluid agent, and the alterations which this itself experiences.

To follow M. Delesse through the large collection of examples which he has amassed for discussion, and which he has discussed, generally with the aid of careful chemical analysis, would be a pleasing but unnecessary task. In clear simple language, the results of the whole inquiry are summed up under the heads of effects on the enclosing rock, according as the metamorphic agency is volcanic, trappean, or granitic, and effects on the eruptive rock.

The effects produced by lava are incontestably due to mere heat, while those observed in the contacts with trap indicate often an action of heated liquid solutions, and often the effect of a rock heated and plastic, but not really fused as lava is seen to be. So granite appears to have become often plastic, and yet not really fused, and the changes which it occasions are not such as mere heat can produce. Here we find M. Delesse apparently taking a view of the once plastic nature of granite and trap, not unlike that presented by Mr. Scrope in regard to the flowing of recent lava.

Mr. Sterry Hunt has recently communicated to the Society a memoir treating generally of the processes by which sedimentary deposits may have been transformed into crystalline rocks. Among other instances by which he is induced to reject great heat as the cause of the metamorphism of sedimentary rocks, he mentions "*unoxidized carbon* in the form of graphite, both in crystalline limestone and in beds of magnetic iron-ore; and it is well known that these substances, and even the vapour of water, oxidize graphite at a red heat, with formation of carbonic acid or carbonic oxide. He refers to the fact, proved by himself, that solutions of alkaline carbonates in presence of silica and earthy carbonates slowly give rise to silicates, with disengagement of carbonic acid, even at a temperature of 212° F., the alkali being converted into a silicate, which is then decomposed by the earthy carbonate regenerating the alkaline salt, which serves as an intermedium between the silica and the earthy base." He thus endeavoured to explain the production of the various silicates of lime, magnesia, and oxides of iron so abundant in crystalline rocks, and, with the intervention of the argillaceous element, the formation of chlorite, garnet, and epidote*.

Mr. Scrope, the distinguished geologist, whose work on the Volcanos of Auvergne has been the delight of every explorer of that singular tract, has again taken the field in defence of the growth of volcanic cones by successive eruptions, against the opinion of Humboldt, Von Buch, Dufrénoy, and Daubeny, which ascribes to elevatory movement many of the most remarkable effects connected with lines and centres of volcanic action. In the examination of this subject, Sir C. Lyell's late determination of the fact that lava-streams have frequently been solidified on a considerable inclination is much insisted on, as removing an objection to the theory of the eruptive origin of cones in which sheets of lava formed a considerable part of the mass. M. Abich has also presented some notices of the structure of Etna, obtained with considerable difficulty in the Val del Bove, which show high inclinations of the stratified masses. In general it appears probable that cones of elevation are at least of rare occurrence, while cones of eruption are numerous; but, as vertical movement of the ground is an essential condition for volcanic excitement at the outset, we must be prepared to admit the probability of its occurrence as a part of volcanic history: and the only questions which remain for calm and serious study in reference to a given volcano are—How much? and at what epoch? Questions not to be answered hastily.

That the earth is still fluid within, under the regions of volcanic action, and ever ready to pour out its melted constituents under the pressure of elastic vapour, is evident by all the phænomena of volcanic excitement. Is this fluidity due to the residual heat of the globe, still effective in these regions, or maintained if not excited here by the chemical process of oxidation—by the decomposition of water, and the reunion of one of its elements with the uncombined bases of the earths, alkalis, and metals? The answer, if taken from volcanic phænomena alone, appears ambiguous. The chemical products of volcanos, indeed, require the admission of water to the roots of the fiery action, and the decomposition of it there; but this seems not decisive of the question whether the bases of the alkalies and earths and metals exist uncombined with oxygen in these situations, chemists of eminence taking different views of the matter.

* Royal Society's Proceedings, May 7, 1857.

If we take earthquakes for our guide, these tremors appear to follow laws which apply to elastic solids, not undulating fluids, and yet they presuppose a shock or displacement, such as a fluid support for a solid crust might well account for.

Mr. Mallet has completed the 'Catalogue of Earthquakes,' on which he has been so long engaged for the British Association. Aided by his son, Prof. J. W. Mallet, he has brought this great work from the earliest notices of history to the end of 1842. From 1843 the labours of M. Perrey, of Dijon, in the same field, may be consulted with equal confidence in their accuracy. Both these authors have increased the value of their work by appropriate discussions in relation to time—by centuries, years, seasons, months, and days—as had also been done with equal ability by Mr. David Milne. They have considered earthquakes also in relation to their numerical distribution in geographical space, and in relation to the rate, extent, and direction of the movement. In many of the tables which are given by those authors to represent the numerical relations of earthquakes to seasons of the year, we find a preponderance of the three earlier and three later months over the six months from April to September.

This appears to be the case throughout Europe and Asia, and conspicuously so in all the northern parts.

In a general Table compiled to illustrate this point by Mr. Mallet, we find, from the fourth to the nineteenth century inclusive, the following number of earthquakes in each month:—

| | |
|---|---|
| January | 228 |
| February | 189 |
| March | 172 |
| April | 147 |
| May | 126 |
| June | 131 |
| July | 148 |
| August | 147 |
| September | 147 |
| October | 176 |
| November | 148 |
| December | 202 |

If these numbers be represented by ordinates at equal distances, they will mark out an annual curve, whose maximum is in January, and minimum towards the end of May.

The number of earthquakes which occur in the first three and the last three months ......=589 and 526
And in the six median months ............=404 and 442

M. Perrey has found by analogous process of tabulation (using also a formula of interpolation which includes the angular value of the age of the moon) that—

1. Earthquakes occur more frequently at the syzygies (new and fullmoon).

2. Their frequency increases at the perigee (when the moon is nearest to us) and diminishes at the apogee (when she is furthest removed).

3. The shocks of earthquakes are more frequent when the moon is on the meridian than when she is 90° removed from it.

Mr. Mallet has re-examined and confirmed these results. He presents a table of no less than 5879 earthquakes in the northern hemisphere and 223 in the southern hemisphere, distributed in months. The northern observations are thus classed in months and in three months :—

| | | |
|---|---|---|
| January | 627 | 1669 |
| February | 539 | |
| March | 503 | |
| April | 489 | 1355 |
| May | 438 | |
| June | 428 | |
| July | 415 | 1366 |
| August | 488 | |
| September | 463 | |
| October | 516 | 1489 |
| November | 473 | |
| December | 500 | |
| | 5879 | |

The predominance is clearly in the month of January, the minimum occurs in the end of June or the beginning of July. The six extreme months give 3158, and the six median months give only 2701. The three consecutive months having most shocks are January, February, and March, the three which have the fewest are May, June, and July.

Those for the southern hemisphere are perhaps too few to be employed with much confidence in a similar way. They seem to give a principal maximum in November, and a second in May, with two minima in March and August. The first three months give 42, the next 56, the third 47, and the last 78. If 56 be taken as the mean, we have

56 — 14 for the first period of three months,
— 0 for the second,
± 9 for the third,
+22 for the fourth.

These extremely curious results, coinciding as they do with the results of many recent researches, which show the reality of the lunar influence on terrestrial magnetism and the temperature and pressure of the atmosphere, seem to point to an influence exerted by the moon's attraction on the condition of the interior masses of the earth. Whether, however, we admit this influence to be sensible on a fluid interior, or effective in generating electrical or other actions, capable of transformation into mechanical force, and however much force we ascribe to such influence, it can never be regarded as a *cause* of the earthquake. It may, by throwing a feeble weight into the scale of force, determine the *time* of the occurrence, but we must look to other and far mightier changes of pressure for the efficient means whereby the earth is made to feel the dread Typhoean agony.

In applying the knowledge we actually possess from the study of special cases to the general problem of the metamorphism of gneiss and other associated rocks, we shall be obliged to consider also the theory of the origin of granite and other unstratified rocks, which, in masses of various dimensions, often show themselves in the metamorphic regions. If we take a general view of the region of Cornwall and Devon (one of the best known countries in this respect, and yet in other respects one of the least known), we shall find the granite of Dartmoor, Bodmin, Godolphin moors, and the Land's End, wrapped round by the stratified rocks, and these generally dipping away from the granite*. Near the junction of the stratified and unstratified rocks are many excurrent granitic veins and many traversing elvan-dykes, and in some parts bands of hornblendic rocks follow the sweep of the strata.

I suppose no one doubts in accepting these granite-bosses as the summits of a great, perhaps continuous, mass of interior rock, elevated at a point of time since the date of the carboniferous strata. Collecting the evidence bearing on the condition of the rock when erupted, it would seem that it had been liquid after the deposition of the bordering slaty rocks, but that it may have been in a considerable degree solidified, before being raised. It seems to be probable that a similar view may be taken of the granitic eruptions of Arran and the district of the Lakes.

Returning to Cornwall, we find the great unstratified mass of serpentine, in the Lizard, bounded by strata on the north, and partly so on the south. On the south the rocks are metamorphic (hornblende-rocks and mica-schist). On the north, the strata are not changed near the serpentine; they do not fold round it, nor dip from it; their strike would go through the serpentine; and it appears to me that in the serpentine-mass surfaces and bands are frequently observable, as if they were the remains of stratification.

It cannot be said in this case that there is evidence of local intrusion of this mass of rock among the deposits of the palæozoic seas, either during their deposition or after their consolidation. We are therefore left to choose between supposing it to be a pre-existent mass of fused rock, round and against which the "killas" was deposited, or regarding it as an originally stratified mass, which has undergone metamorphism at a later period; but this process would not require or even admit of the pervading action of a very high temperature, for there is no thermal effect on the border. On examining the rock chemically, and finding it to be a hydrosilicate of magnesia, we seem to be reduced to the supposition that this is a case of metamorphism in presence of water, if not wholly by the agency of watery solutions. Perhaps the diallagic rocks which

* An excellent MS. map of the district by Mr. Whitley, of Truro, shows this fact very clearly.

prevail in the north-eastern parts and run in bands more or less parallel to the leading strata may hereafter furnish fresh data for the decision of this problem: if the rock were originally igneous, these may be the least-changed parts of the deposit; if it were originally sedimentary, they may be the most-changed parts.

We may employ the same mode of reasoning for examining the results obtained by Mr. Marshall in treating of the granitic masses of the Lake-district in relation to the undoubted metamorphic strata which surround them. In this tract, as in Cornwall, there is very little gneiss or mica-schist, except at one or two points, in contact with granite or very near to syenite. The strikes of the strata do not sweep round the granite-bosses; veins pass from the igneous rocks, and porphyry-dykes emulate the elvan of Cornwall. The granitic masses seldom, if at all, appear to be located on the axis of movement, or to mark out special areas of disturbance (even the granite of the Calder and the syenite of Carrock can hardly be excepted); on the contrary, the strikes of the strata run up to them as if to traverse them, and the dips of the strata suffer no special or exceptional derangement at the contact with them. Yet the metamorphism of the rocks which border these granites is very fully manifested, and in such a way as to be continually greater towards the granite, or to some other central space, where, if granite be not visible at the surface, it may, without difficulty, be supposed to exist beneath.

The explanation offered by Mr. Marshall* of these phænomena proceeds on the supposition that the strata of the district have been exposed to the action of the general heat of the globe, by reason of the depression to which they have been subjected; that this general heat has been productive of effects varying with the nature of the rock, and graduated by the scale of applied heat, granite being the extreme term of metamorphism, viz. complete fusion, followed by recrystallization. The whole metamorphic tract has been since subject to displacement.

In some late examinations of a part of this Lake-country, I followed the footsteps of Sedgwick in the solitary glens of Black Comb, and the metamorphic region on its northern and eastern slopes. In this vicinity we see clearly marked a band of metamorphic green slates, between the Skiddaw slate of Black Comb and the granite and syenite of Eskdale. The metamorphism is various in kind and in degree. The stratification often remains distinct, and is always traceable; cleavage is traceable; agate-concretions appear and are elongated in the dip of the cleavage; some bands of hornblendic rock alternate. On approaching the granite, the masses grow porphyritic; these greenish porphyries are traversed by syenitic veins, which run along joints and fractures; parallel to these veins for a very short distance the felspathic base of the porphyry is reddened. Syenitic rocks in mass next appear; and further on, irregularly, granite diversifies the syenite, and finally appears alone. It is only in one small narrow ridge near Bootle

* See Report of the British Association for 1858.

that these facts can be completely traced in the compass of half a mile. In the mountain of Black Comb, nearly in the southward prolongation of this ridge, and in the lower strata (Skiddaw slate), are seen bands or dykes of granite ("elvany"), lying in the slate series, and apparently, at least for short distances, parallel to the strata. The strata are partly altered to what is often called "flinty slate," a change which amounts to little more than loss of colour, and gain in hardness.

The general conclusion to which Mr. Marshall has been conducted in the course of his long study and intimate knowledge of the Lake Mountains is thus expressed:—The phænomena observed may be best explained by the supposition that the whole series of rocks, granites included, are metamorphic sedimentary strata *in situ*, or in their natural order of position, and that the slaty rocks alternating with the porphyries are to be accounted for on the supposition that they are, by chemical composition, less fusible, less easily acted upon by heat, than the porphyritic beds, and have therefore been only hardened, retaining the cleavage and stratified structure, whilst the more fusible rocks have been changed into porphyries.

This supposed original inequality in the degree of fusibility has been in some degree submitted to the test of experiment: portions of the Skiddaw slate, green slate, and porphyritic bands, in powder, have been placed in crucibles and gradually heated. At a good red heat the porphyry puffed up, fused, and ran over the edge of the crucible, in the shape of a brown glassy slag. At a white heat the Skiddaw slate fused into a grey glassy slag; and lastly, at a strong white heat the green roofing-slate also fused into a black glassy slag. Thus the slate-rocks appear to be decidedly less fusible—less easily acted upon by heat than the porphyries.

The same result was obtained in fusing fragments of Skiddaw slate, Skiddaw granite, and porphyry, in a common reverberatory furnace: a white heat was required to fuse them, but the granite and porphyry melted much more readily than the clay-slate.

When pressure was employed to consolidate the powders of granite, Skiddaw slate, and porphyry, in strong iron tubes, and the compressed mass was secured by screwing down, the melting occurred in each case at a lower heat with pressure than without: a red heat was sufficient to fuse them; when slowly cooled they resumed a stony texture, and did not resemble the glassy slags produced by fusion without pressure.

A large mass of the syenite of Charnwood Forest was melted in a reverberatory furnace, and slowly cooled; it showed, as in the well-known trials by Mr. G. Watt on the basalt of Rowley Rag, every gradation of texture, from that of glassy slag to stony granular and even porphyritic structure.

By exposing the glassy slag to heat below fusion for two or three weeks, a stony texture is found to be induced.

It is much to be wished that experiments of this kind may be repeated, under pressure, and, if practicable, in presence of moisture, for in every view of the origin of the plutonic rocks moisture must be conceived to have been present. According to the theory of a cooling globe, the influence of the atmosphere and ocean must have been very strongly felt in the formation of compounds by consolidation from fusion; while, according to the theory of volcanic heat being generated from the contact of water and unoxidized bases of alkalies, earths, and metals, some trace of water should appear, as, in fact, it does in the minerals crystallized in lava.

In this speculation Mr. Marshall follows out the views first proposed by Mr. Babbage in his notices of the temple of Jupiter Serapis* —views securely founded on the inevitable effect of the vertical displacement of the interior surfaces of equal temperature by any displacement of matter at the surface of the earth or alteration of the areas of sea and land. Every day, by the removal of matter from the land and the deposition of it in the sea, these isothermal surfaces do undergo vertical displacement, and the masses of the earth's crust are in consequence changed in bulk and changed in place.

Materials of unlike nature are unequally affected, some expanding by heat, others contracting, while thermo-electric currents generated by these inequalities contribute to new resolutions and new combinations among the elements of matter. Metamorphism in a large and general sense thus becomes a normal and a necessary phænomenon.

If we suppose a change of temperature of 100° Fahr. to cause expansion in a solid mass 500 miles across, this would occasion a change of linear dimension of above a quarter of a mile in limestone and sandstone. If the pressure occasioned by this were relieved by one vertical fault, it must be 16 miles in height; if by one general curve upwards, it would have an elevation in the middle of about 8 miles. Though in fact neither of these assumptions as to the form of the surface of relief can be adopted, they show how great is the *power* of changing form and relative height generated by changing temperature in rock-masses. It may here be mentioned that Mr. Adie found a rod of Carrara marble to acquire a *set*, and to be permanently elongated by the application of heat. Clay, on the other hand, is known to be permanently shortened. "The expansion and contraction of strata may form rents and veins, produce earthquakes, determine volcanic eruptions, elevate continents, and possibly raise mountain-chains†."

The more we consider the conditions under which the mass of the earth is held together, the more clear grows our conviction that internal causes of change of figure, if not of volume, do really exist and may be effective. Dr. Siljeström, of Stockholm, calls attention to a cause of dilatation and contraction which must be supposed to exist, or at least to have existed in the fluid mass, viz. difference of temperature in the different parts of this mass. By the extinction of this difference, through more complete mixture, in any given case and in the same chemical substance, a change of total volume would

* See Geol. Proc. vol. ii. p. 72, Quart. Geol. Journ. vol. iii. p. 186, and Ninth Bridgewater Treatise, p. 209.

† Babbage, Ninth Bridgewater Treatise, p. 218.

necessarily take place—such that, assuming iron to be the substance, 200° the difference of temperature, and $\frac{1}{1,000,000}$ of the earth's mass to be affected, the resulting change of volume would be not less than five or six times the bulk of Vesuvius*.

Again, the fusion of any part of the interior mass previously solid, or the solidification of any part previously fluid, must occasion considerable change of volume. According to Bischoff, granite, in passing from a fluid to a solid state, appears to undergo a contraction from 1·0000 to ·7481, trachyte to ·8187, and basalt to ·8960†.

Nor is this all the effect which may be looked for from such changes. The distribution of heat is modified, and the specific gravities of adjacent masses are altered. Granting only partial solidification from a fluid mass persistent beneath, we shall be prepared to admit that the solid may have quite a different specific gravity from the fluid out of which it has been separated‡.

From such causes as these now suggested, changes of level would be inevitable; slow indeed and variable in position, but of long duration, and of a magnitude enough to satisfy the reasonable demands of all but cataclysmal hypothesis.

Such, Gentlemen, are the thoughts which rise in my mind as I follow the Ariadnean thread of your annual labours. On some of these weighty subjects we are not all entirely agreed; on others we have not even laid securely the basis of a lasting agreement. Let us not regret this want of unity, nor stifle, under forms of general acquiescence, the real differences of interpretation to which unlike phænomena and unequal opportunities of study ought to conduct us.

The theory of geology is nothing less than the physical history of the globe—and this history is to be extorted from the archives of nature by question upon question after doubt upon doubt. When geologists cease to inquire, when a dogma is quoted to relieve a doubt, when faith in the dictum of some favourite author outweighs the evidence in the book of nature, we may indeed have much of form in our geology, but little of truth and energy—"Ipsique cæci, aliorum oculis videmus, si quid."

Ours is no coasting voyage by the sunny shores of some well-havened bay; we steer across the undiscovered ocean of truth, with compasses in need of correction, under the canopy of cloud and darkness which involves the origin of things; one only faithful guide across the world of ancient force and time—the permanence of the laws of nature, the perpetual obedience of natural phænomena to the constant will of the great Maker, with whom is no variableness, neither shadow of turning, the same yesterday, to-day, and for ever.

* Report of the British Association for 1858, p. 23.

† Bischoff (Leonhard and Bronn, N. J. 1841), quoted by Hennessy in Phil. Trans. 1851.

‡ Phillips in Encyclopædia Metropolitana (art. Geology, 1832) and Manual of Geology, 1854, p. 585.

THE

# QUARTERLY JOURNAL

OF

# THE GEOLOGICAL SOCIETY OF LONDON.

## PROCEEDINGS

OF

## THE GEOLOGICAL SOCIETY.

### March 24, 1858.

George C. Greenwall, Esq., Radstock, near Bath, Samuel Dobson, Esq., Treforest, Glamorganshire, Joseph James Forrester, Esq. (Baron de Forrester), Oporto, Henry Becket, Esq., Wolverhampton, William Fletcher, Esq., Tarn Bank, near Cockermouth, George Highfield Morton, Esq., London Road, Liverpool, Elkanah Billings, Esq., Montreal, and George Rowdon Burnell, Esq., 14, Lincoln's Inn Fields, were elected Fellows.

The following communications were read:—

### 1. *On a Protrusion of* Silurian Rock *in the* North *of* Ayrshire. By J. C. Moore, Esq., F.R.S., F.G.S.

The productive coal-fields of Ayrshire terminate abruptly to the north at the town of Ardrossan, from whence, for some miles along the coast, red sandstones and conglomerates prevail. These are correctly coloured in the maps of Phillips and of Sharpe as Old Red Sandstone, though I am not aware upon what precise grounds. At Ardrossan, and for two or three miles at least to the north, the two formations are caused by a fault to abut against each other; so that

*Section of a part of the Coast of Ayrshire, North of Ardrossan.* Length about 5 miles.


1. Coal-measures.
2. Red Sandstone, with white quartz-pebbles at the bottom.
3. Coarse conglomerate of white and pink quartz.
4. Red Sandstone and conglomerate, without quartz-pebbles.
5. Sandstone.
6. Sandstones, with small quartz-pebbles.
7. Silurian slates, purple, green, and black.
8. Trap.
9. Greenstone.
10. Porphyry.

proof by superposition is wanting: no fossils, I believe, have been found in the red sandstones; and the coast of Arran opposite gives an example of sandstones and conglomerates indistinguishable in mineral type, some superior to, and others underlying the coal-measures. Having lately discovered a patch of Silurian rock in this district, which appears to me conclusive of the age of the sandstone series, it may be worth while to give details of the section.

From Saltcoats to Ardrossan (see fig.) the coal-measures are seen on the shore, dipping S.E., and consisting of the usual alternations of sandstones and shales with imbedded plants, beds of coal, and limestone. Approaching the harbour of Ardrossan, these beds dip S.E. at an angle of 45°, when a mass of trap sets in, which, running out to sea, forms a natural breakwater. To the north of the trap begin the red sandstones, also dipping S.E., but at a lower angle. They are well exhibited in a quarry immediately north of the town. The top beds are of a marly nature; and it is only near the bottom of the section that the strata contain a few pebbles of white quartz. For four miles the shore is composed of the same formation, still dipping S.E. until we reach a point where the beds for a short distance dip N.W., at a low angle; a little further to the N., near the House of Ardneil, the sandstones are vertical for several yards, after which we arrive at a spot where a sudden change in the rock, attended with the greatest disturbance, is exhibited. A mass of light- and dark-green, claret-coloured, and black shales and arenaceous schists, veined with calc-spar, and contorted in every conceivable way, has here been forced up through the sandstones and conglomerates, which, to the south of the disturbance, are pitched up to a right angle, while to the north they are elevated to about an angle of 50°.

The breadth of this intruded mass is about 50 yards; and I think it impossible for any geologist acquainted with the aspect of the Silurian rocks in the south of Ayrshire to doubt that this is of Silurian age. In mineral constitution, in cleavage, in variety of colour, in the violence they have been subjected to, they exactly resemble Silurian rocks, and in all these respects they present the strongest contrast to the Devonian rock with which they are in contact. It also seemed to me on the spot equally impossible to doubt that the Devonian beds to the north are the very bottom of that series, as here developed. They can be observed for several yards overlying the Silurians,—of the squeezes and contortions of which they do not partake, having merely been tilted without further derangement. The lowest bed is a dark-red sandstone and conglomerate of small dark pebbles, apparently Silurian, but containing no white quartz-pebbles. This continues along the shore, traversed by a great dyke of greenstone, till we arrive at the ruins of Portencross Castle, where the dark-red sandstone and conglomerate is covered by a very coarse conglomerate of pink and white quartz-pebbles, of the size of a child's head. This is succeeded by sandstone, with occasional layers of small white quartz-pebbles, —the sandstone near the top being marly, and thus agreeing in appearance with the sandstone first described, near Ardrossan. It is cut through by a dyke of red porphyry, about 12 feet thick, which has forced itself up, and spread itself over the sandstone, forming the Hill of Goldenberry. This capping of porphyry, judging by the eye, cannot be less than 300 feet thick. The junction of the sandstone and porphyry is well seen in a perpendicular inland cliff; and the whole scene will well repay the pains of a visit, from its picturesque beauty, independent of its geological interest. The sandstones continue to dip north as far as they are seen, until they are cut off by an arm of the sea.

The Devonian beds immediately in contact with the two sides of the Silurians are not identical: the dark-red conglomerate and the coarse quartzose conglomerate, which are seen to repose on the Silurians to the north, do not occur on the south; and in their place we find, as above stated, vertical beds of sandstone similar to that which forms the base of Goldenberry Hill, and to that which forms the whole coast to Ardrossan. It would appear that the elevation of the Silurian rock has been attended by a fault; and, while the lowest beds of the Old Red Sandstone are brought up on the north, a portion of the upper beds on the south side of the fault have been thrown back to a perpendicular position.

The nearest Silurian rocks to this spot as yet known are those in the parish of Lesmahago, on the opposite or south side of the Ayrshire and Lanarkshire coal-field, distant upwards of 30 miles across the strike. These were described by Sir Roderick Murchison in the 12th vol. of the Quart. Journ. Geol. Soc. In comparing the two sections, it will be observed that in both cases the Devonian series, near its base, contains coarse conglomerates of well-rounded white and pink quartz-pebbles; but they differ markedly in this, that on the Logan water no unconformability was observed between the bottom of the Old Red Sandstone and the Silurians containing the *Eurypteri*, &c., which are referred by Sir R. Murchison, on palæontological grounds, to the Ludlow period. I have compared the Portencross Silurians with those of the south of Ayrshire; but this conclusion, resting solely on mineral characters, cannot rise higher than a mere probability.

In the elaborate memoir* on the geology of the Isle of Arran, by Sedgwick and Murchison, it is shown that the axis of elevation of the Old Red Sandstone, the coal-measures, and the red sandstones which are superior to the coal, passes through North Sannox on the coast, and that these formations dip very regularly N.N.W. and S.S.E. respectively on the two sides of this axis. The strike of the beds, therefore, is E.N.E.; and if the axis be prolonged on the map from North Sannox to the coast of Ayrshire, it will strike the coast close to Portencross, where the above-described protrusion of Silurian rocks occurs. The coincidence is too striking to be accidental: it is clear that the exertion of force which has elevated the Devonian beds and the coal-measures in Ayrshire is the same as that which has produced the same effect in Arran, distant about 10 miles. But it is to be observed also, that this axis runs E.N.E., that is to say, exactly parallel to the strike of all the lower Silurian rocks in the south of Scotland. Now it is certain, from many sections described by many different observers, that the Silurian rocks had undergone upheavals and convolutions, and had had their present strike impressed upon them, previously to the deposition of the Old Red Conglomerates,—while the facts I have mentioned above prove that an exertion of force very different, indeed, in energy, but exactly corresponding in direction, reoccurred after the close of the Permian period.

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## 2. *On the* Kelloway Rock *of the* Yorkshire Coast. By John Leckenby, Esq. (Communicated by John Morris, F.G.S.)

[Plates I. II. III.]

Among the more interesting features in the geology of the east coast of Yorkshire is the Kelloway Rock, whether compared, in its extraordinary development, or in the great variety of its fossils, with its Wiltshire prototype.

The Kelloway Rock is first seen in the cliff a short distance to the south of Gristhorp Bay, and here, but for its position below the Oxford Clay, and the presence of some characteristic fossils, there is little about the thin band of calcareous pisolite in which these fossils occur to identify it with the ochreous and arenaceous

* Transact. Geol. Soc. ser. 2. vol. iii. p. 21.

deposits as it usually appears. This band, which immediately underlies the Oxford Clay, never exceeds 5 inches in thickness, and after a course of 50 yards, thins out into a bed containing much decomposed lignite, and which at this point forms a passage into the Oxford Clay above. The great mass below, presenting a thickness of nearly 30 feet, is entirely unfossiliferous. The thin deposit at the top, and the passage into beds of lignite, seem to indicate the gradual filling up of some shallow sea of that period.

From the southern extremity of Gristhorp Bay, the Kelloway Rock is seen on the cliff, from the base to a height of fifteen to twenty feet, presenting, by its laminated markings and longitudinal fissures, an appearance of artificial masonry. It gradually ascends northward (the fossiliferous band having disappeared), until, about midway in the bay, it passes inland.

The underlying Cornbrash is well developed about halfway up the cliff, and has been occasionally quarried and sent to Hull for conversion into cement.

The projecting point of Red Cliff presents the next important section, and here the Kelloway Rock assumes its more general lithological character. Here also occur in abundance two species of *Ammonites* which characterize the rock in Wiltshire (*Am. Kœnigi* and *Am. sublævis*), so exactly similar, that if mixed in a cabinet, it would be next to impossible to separate the northern from the southern examples. Here two distinct zones of fossils, and the following section, in a descending order, may be observed.

| | feet. |
|---|---|
| A. Moderately compact irony sandstone, 1½ foot thick, traversed by darkened veins of the same metallic character, across which *Ammonites* are often placed, and which divide the fossil into separate portions when an attempt is made to extract it. This bed is characterized by the presence of *Am. Kœnigi*, *Am. flexicostatus*, and *Belemnites tornatilis*. *Am. flexicostatus* is here special to the bed. | |
| B. Loose friable sand and sandstones, without fossils . . . . . . | 4 |
| C. Bed similar to A, but much richer in organic remains, containing, besides *Am. Kœnigi* and *Belemnites tornatilis*, *Am. sublævis*, *A. Gowerianus*, *A. Chamuseti*, *Pholadomya acuticosta*, *Modiola pulchra*, *Terebratulæ*, *Gryphæa dilatata*, and other shells. It is more nodular and cherty than the upper zone, and its fossils are better preserved | 1½ |
| D. Compact sandstone, entirely unfossiliferous, with the rare exception of a stray Belemnite or Ammonite in the centre of one of its huge blocks . . . . . . . . . . . . . . . . . . . . . . . . | 20 |

The same divisions obtain at the Castle Hill, Scarborough, which point next claims our attention. A fine section near the pier may be advantageously examined, and it is here that a flooring of the rock has yielded an abundance of its finest and most characteristic fossils. The upper zone, as at Red Cliff, contains *Ammonites*

*Kœnigi*, *Am. flexicostatus*, *Belemnites tornatilis*, all which, however, occur in greater abundance and perfection in the lower zone, which is the chert-deposit. Amongst the Cephalopods are

| | | | |
|---|---|---|---|
| Ammonites gemmatus | Common. | Ammonites lenticularis | Very rare. |
| —— Duncani | Common. | —— Arduennensis? | Very rare. |
| —— Gowerianus | Not rare. | —— perarmatus | Scarce. |
| —— athleta | Not rare. | —— Gulielmi | Common. |
| —— lunula | Scarce. | —— bipartitus | Rare. |
| —— Chauvinianus | Rare. | | |

Here it is that the great bulk of the Mollusca and Gasteropoda afterwards enumerated have been obtained.

At this point *Am. Gulielmi* is found in tolerable abundance; but, although *Am. Calloviensis* is recorded by W. Smith and by Prof. Phillips as having been found here, and, in fact, is mentioned by these authors as one of the fossils which first led to the identification of the rock with the Wiltshire beds, I have nowhere seen a specimen of true *Am. Calloviensis* from Yorkshire. Prof. Phillips's figure does not agree either with typical Wiltshire specimens, or with the figures of Sowerby or D'Orbigny.

On the north side of Scarborough Castle, numerous blocks of this rock, derived from section D, but having portions of C attached, formerly strewed the base, the accumulated débris of centuries from the undermining and falling over of the cliffs adjacent.

A few years ago the surfaces of these blocks were found to consist of cherty calcareous nodules, filled with fossils, and so diligently have these been explored, that now hardly a block is to be found to reward the industrious collector.

The Kelloway Rock finally disappears from the cliffs about 200 yards north of the Castle. Its upper beds were removed about two years ago in preparing the ground for the erection of a row of houses, and many characteristic fossils were then brought to light, including examples of *Am. Gulielmi* and *Am. gemmatus*, of unusual dimensions.

At all the points enumerated, in conformity with a pretty general law, the great deposit of fossils is at or near the top of the bed; while all below, for a thickness often of 20 feet, is solid, compact sandstone, as at Hackness, where quarries of this rock have yielded the material for the erection of some of our public buildings.

The Kelloway Rock ranges inland from Gristhorp to Oliver's Mount, where it keeps the lower part of that curious ridge*; the middle being composed of Oxford Clay: the whole is surmounted by calcareous grit. The eye of the practical agricultural geologist will detect the argillaceous belt of Oxford Clay as he passes on the railway along the valley, as well as on the hills on the opposite side. In the parallel valley westward, the Kelloway Rock may be examined in a quarry used for extracting material for repairing roads. Between this point and Hackness I have not observed it; but the peculiar

* One or two springs of water mark its junction with the clays of the Cornbrash beneath.

ridges and escarpments formed by the resistance of the calcareous grit, and the denudation of the Oxford Clay, characterize all the hills around Scarborough, the Kelloway Rock occupying the valleys. At Newton Dale the upper beds thin out, and there is a paucity of organic remains, compared with Hackness and Scarborough, but *Gryphæa dilatata*, *Trigoniæ*, and *Am. Gulielmi* may be obtained.

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## *Organic Remains.*

The following is a catalogue of the fossils of the Kelloway Rock of Yorkshire, with descriptions of some new or imperfectly understood species:—

### *Cephalopoda.*

Ammonites, sublævis, *Sowerby.*
—— ordinarius, *Bean, MS.*
—— rugosus, *Leckenby.*
—— Gowerianus, *Sowerby.*
—— reversus, *Simpson, MS.*
—— Vertumnus, *Bean, MS.*
—— Poculum, *Bean, MS.*
—— Chauvinianus, *D'Orbigny.*
—— alligatus, *Bean, MS.*
—— Arduennensis, *D'Orbigny.*
—— binatus, *Bean, MS.*
—— Kœnigi, *Sowerby.*
—— Athleta, *Phillips.*
—— gemmatus, *Phillips.*
—— Gulielmi, *Sowerby.*
—— Murrayanus, *Simpson, MS.*
—— Placenta, *Bean, MS.*
—— Lamberti, *Sowerby.*
Ammonites putealis, *Bean, MS.*
—— turgidus, *Bean, MS.*
—— gregarius? *Bean, MS.*
—— Lunula, *Zieten.*
—— Chamuseti, *D'Orbigny* (= *A. lenticularia*, Phillips).
—— funiferus, *Phillips.*
—— hyperbolicus, *Simpson, MS.*
—— glabellus, *Bean, MS.*
—— conterminus, *Bean, MS.*
—— bipartitus, *Zieten.*
—— Baugieri, *D'Orbigny.*
*a* Belemnites tornatilis, *Phillips* (= *B. Puzosianus*, D'Orbigny).
*a* —— hastatus, *Blainville.*
*a* —— gracilis, *Phillips.*
*c* Nautilus hexagonus, *Sow.*

Note.—Of the foregoing list of *Ammonites*, one species *Am. alligatus* ascends to the Calcareous Grit above. All the others (except *Am. binatus*, of which a dwarfed variety is found in the Oxford Clay) are peculiar to the Kelloway rock.

### *Gasteropoda.*

*a* Alaria bispinosa, *Phillips.*
Natica (a cast).
*b* Chemnitzia vittata (?), *Phillips* (imperfect casts).
Cerithium abbreviatum (n. s.).
—— Culleni (n. s.).
*b* Littorina punctura, *Bean, MS.*
*b* —— ornata, *Sowerby.*
Turbo sulcostoma, *Phillips.*
*b* Turbo elaboratus, *Lycett & Morris.*
Pleurotomaria guttata, *Phillips.*
—— arenosa, *Bean, MS.*
*b* —— granulata, *Sowerby.*
*a* —— depressa, *Phil.*
—— striata, *Bean, MS.*
Patella? graphica, *Bean, MS.*
*a* Actæon retusus, *Phillips.*
*c* Dentalium annulatum, *Bean, MS.*

### *Brachiopoda.*

*b* Terebratula ornithocephala, *Sow.*
*c* Rhynchonella varians, *Schlotheim.*
Lingula lævis, *MS.* Mr. Bean's Collection.
Discina (Orbicula) centralis, *MS.* Mr. Bean's Collection.

### *Conchifera.*

*b* Gryphæa bullata, *Sowerby.*
*c* —— dilatata, *Sowerby.*
*c* Anomia inæquivalvis, *Phillips.*
Ostrea undosa, *Bean, MS.*
—— archetypa, *Phillips.*
*c* —— Marshii, *Sowerby.*

Ostrea canaliculata, *Bean, MS.*
—— procerula, *Bean, MS.*
——. A peculiarly elongated smooth species approaching *Vulsella.*
—— striata, *Bean, MS.*
c Pecten demissus, *Phillips.*
b —— fibrosus, *Phillips.*
c —— vagans, *Sowerby.*
c —— abjectus, *Phillips.*
c —— arcuatus, *Sowerby.*
b Lima duplicata, *Sowerby.*
—— Phillipsii, *D'Orbigny.*
—— notata, *Goldfuss.*
c Avicula inæquivalvis, *Sowerby.*
a —— ovalis, *Phillips.*
c —— Braamburiensis, *Phillips.*
—— clathrata, *Bean, MS.*
b Perna rugosa, *Goldfuss.*
a Pinna mitis, *Phillips.*
c Modiola dipartita, *Sowerby.*
c —— cuneata, *Sowerby.*
—— pulchra, *Phillips.*
a Cucullæa æmula, *Phillips.*
b —— elongata, *Sowerby.*
b —— clathrata, (n. s.).
—— minima (n. s.).
Solemya Woodwardiana (n. s.).
c Nucula lacryma, *Sowerby.*
c Trigonia costata, *v.* pulla, *Sowerby.*
c —— elongata, *Sowerby.*
—— clavellata, *Parkinson.*
c Trigonia clavellata; a variety, much less produced posteriorly, and with the tubercles crowded on the anterior margin.
b Cardium cognatum, *Phillips.*
b —— citrinoideum, *Phillips.*
—— subdissimile (?), *D'Orbigny.*
a —— Crawfordii (n. s.).
Lucina lirata, *Phillips.*
b —— crassa, *Sowerby.*
Corbis ovalis, *Phillips.*
—— lævis, *Sowerby.*
b Astarte lurida, *Sowerby.*
b —— minima, *Phillips.*
b —— politula, *Bean, MS.*
b Unicardium depressum, *Phillips.*
b —— sulcatum, *Bean, MS.*
c Isocardia tumida, *Phillips.*
b —— minima (?), *Sowerby.*
b —— triangularis, *Bean, MS.*
——? clarissima, *Bean, MS.*
c Anatina undulata, *Sowerby.*
—— versicostata, *Buvignier.*
b Pholadomya acuticosta, *Sowerby.*
b —— ovalis, *Sowerby.*
—— carinata (?), *Goldfuss.*
b Myacites calciformis, *Phillips.*
b —— decussatus, *Phillips.*
b —— securiformis, *Phillips.*
a —— recurvus, *Phillips.*
c Goniomya V-scripta, *Sowerby.*
c Gresslya peregrina, *Phillips.*

### *Crustacea, Annelida, &c.*

c Glyphæa rostrata, *Phillips.*
c Serpula intestinalis, *Phillips.*
c Imperfect remains of *Cidaris* and
c Encrinal stems.

### *Remains of Vertebrata.*

c Palatal bones and teeth of Fishes; and vertebræ, teeth, and bones of Saurians.

### *Vegetable Remains.*

c Dicotyledonous wood and remains of *Cycadeæ* (imperfect) are sometimes found in the Kelloway Rock of Scarborough.

NOTE.—In this list, the species marked *a* occur also in the bed above, or the Oxford Clay; the letter *b* indicates that the species are found in the bed below, or Cornbrash; *c*, that they are common to all the three deposits.

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## NOTES ON THE FOSSILS.

### 1. AMMONITES SUBLÆVIS, Sowerby.

*Locality.* Red Cliff only.

### 2. AMMONITES ORDINARIUS, Bean, MS.

This Ammonite approaches in general form *Am. Harveyi,* but the ribs bend more towards the aperture, and the increase of the volutions is somewhat greater. The angle formed by the ribs in passing over the back gives it a somewhat keeled appearance. Its claims for distinction as a species are weakened by the existence of many intermediate gradations of form between it and *Am. sublævis,* all of which in the adult shell become smooth and hardly distinguishable from each other.

*Localities.* Near Gristhorpe Bay, and at Red Cliff.

3. Ammonites rugosus, Leckenby.

Gibbous, deeply umbilicated, ribs very thick and strong, separated by wider spaces. Aperture rounded, indented one-fourth by the succeeding whorl.

*Locality.* Near Gristhorpe Bay.

4. Ammonites Goweriantus, Sowerby. Pl. I. fig. 1*a*–1*d*.

Young shells much resemble *Am. Calloviensis,* but in the adult the ornamented square back becomes rounded in this species.

5. Ammonites reversus, Leckenby (Simpson, MS.). Pl. I. fig. 2.

Discoid; of slight volutional increase, back rounded, ribs very sharply defined, bifurcating at the middle of the whorl, and then bending very decidedly from the aperture. Occasionally an entire rib is introduced. Aperture rounded. Scarcely indented by the succeeding whorl.

*Locality.* The Castle Rock, Scarborough.

6. Ammonites Vertumnus, Leckenby (Bean, MS.). Pl. I. fig. 3*a*, 3*b*.

This Ammonite appears to approach most closely to *Am. Mariæ,* D'Orb.; the ribs are strong and cord-like, forming coarse folds on the back.

*Locality.* Near Gristhorpe Bay.

7. Ammonites Poculum, Leckenby (Bean, MS.). Pl. I. fig. 4*a*, 4*b*, 4*c*.

Discoid; sides flattish, back rounded, ribs prominent near the inner margin, dying out before they reach the back, where their place is supplied by numerous slender ones, which pass uninterruptedly across it. In some specimens the ribs near the inner margin are so strong as to become tubercular. Aperture circular, slightly indented by the succeeding whorl.

*Locality.* Near Gristhorpe Bay.

8. Ammonites Chauvinianus, D'Orbigny.

I have referred this Ammonite to *Am. Chauvinianus* on the authority of Dr. Oppel, who identified it without hesitation.

*Locality.* The Castle Rock, Scarborough.

9. Ammonites alligatus, Leckenby (Bean, MS.). Pl. II. fig. 2*a*, 2*b*.

Discoid; sides flatted, especially in the adult; back gently rounded; ribs numerous, entire on the sides of the whorl, bifurcating across the back; volutions deeply constricted at intervals, as in *A. rotula* and other species. Aperture subquadrate, scarcely indented by the succeeding whorl.

*Localities.* Near Gristhorpe Bay, and Scarborough Castle Rock.

10. AMMONITES ARDUENNENSIS (?), D'Orbigny.

*Ammonites subtensis*, Bean, MS.

The ribs are much more delicate and numerous than in D'Orbigny's figure, but there are no other distinctive features.

*Locality*. The Castle Rock, Scarborough.

11. AMMONITES BINATUS, Bean, MS.

This Ammonite approaches *Am. Bakeriæ*, but the foliations of the septa are much more simple, and in the adult the sides are flatter. In some examples, the opposing ribs do not meet in position on the back, but appear as if dislocated, and there is a flattish space intervening.

*Locality*. The Castle Rock, Scarborough.

12. AMMONITES KŒNIGI, Sowerby.

This is one of our most abundant Ammonites. Perfect specimens, 5 inches in diameter, are not uncommon, and I have seen fragments of individuals much larger.

*Localities*. Red Cliff, and Scarborough Castle Rock.

13. AMMONITES ATHLETA, Phillips.

The inner whorls of this species readily distinguish it from *A. perarmatus*.

*Locality*. Castle Rock, Scarborough.

14. AMMONITES GEMMATUS, Phillips.

This is an abundant, but most variable species. Specimens, 5 inches in diameter, are not uncommon. It passes into *Am. Duncani* by imperceptible gradations.

*Localities*. Near Gristhorpe Bay, and Scarborough Castle Rock.

15. AMMONITES GULIELMI, Sowerby.

*Ammonites Rowlstonensis*, Young and Bird.

This has also been an abundant and thriving Ammonite in the Callovian Sea. It is often marked in cabinets as *Am. Calloviensis*.

*Localities*. Near Gristhorpe Bay, and Scarborough Castle Rock.

16. AMMONITES MURRAYANUS, Simpson, MS.

Discoid; sides of the whorls flat; their inner margins squarish, of slow volutional increase, ribs slender, straight, with spines or tubercles on the outer margin. An inner row of tubercles on the outer whorl of aged examples. Aperture a parallelogram, more than twice as long as broad; not indented by the succeeding whorl. Diameter 12 inches; greatest thickness $\frac{3}{4}$ inch.

*Locality*. The Castle Rock, Scarborough.

17. AMMONITES PLACENTA, Leckenby (Simpson, MS.). Pl. II. fig. 1.

Slightly gibbous; inner volutions nearly concealed; principal ribs curving regularly and gracefully towards the aperture, occasionally bifurcating, but more frequently entire, with two or three shorter ones introduced between them, which all pass over and form a crenulated back or keel. Aperture elliptical, two-thirds indented by the succeeding whorl.

*Locality*. The Castle Rock, Scarborough.

18. Ammonites flexicostatus, Phillips.

*Localities*. Throughout the entire range.

19. Ammonites Lamberti, Sowerby.

*Ammonites longævus*, Bean, MS.

This Ammonite approaches *Am. flexicostatus*, but in *flexicostatus* there are two or three smaller ribs between each principal one; whereas, in *Am. Lamberti*, they simply bifurcate, and are much less incurved than in the former species.

*Locality*. The Castle Rock, Scarborough.

20. Ammonites putealis, Leckenby (Bean, MS.). Pl. II. fig. 3*a*–3*c*.

Discoid; whorls rounded near the umbilical margin, flatter in the middle, and again rounded towards the keel; ribs prominent, obtuse, occasionally bifurcate, slightly undulating, and finally bending towards the aperture, where they become enlarged, but do not pass over the back; keel prominent. Aperture indented $\frac{1}{5}$th by the succeeding whorl.

*Locality*. The Castle Rock, Scarborough.

21. Ammonites turgidus, Bean, MS.

This is not a satisfactory species; the outer whorl is entirely devoid of ornamentation, and may probably be the adult stage of the preceding, or some other species. Without an examination of the inner whorls the question cannot be decided.

*Locality*. The Castle Rock, Scarborough.

22. Ammonites gregarius (?), Bean, MS.

Except in its greater comparative thickness, which renders the umbilicus deeper, and the somewhat more robust character of the ribs, I cannot distinguish this from *Am. flexicostatus*.

*Locality*. South side of the Castle Rock, Scarborough.

23. Ammonites Lunula, Zieten.

This species, which is not uncommon, agrees so well with the description and figures of D'Orbigny, as to leave no doubt of its identity.

*Locality*. North side of Scarborough Castle Rock.

24. Ammonites Chamusseti, D'Orbigny.

*Ammonites lenticularis*, Phillips.

*Locality*. Red Cliff only.

25. Ammonites funiferus, Phillips.

This is a much more depressed species than *Am. Chamusseti*, and the intricate character of the foliations of the septa also distinguish it.

*Locality*. Red Cliff only.

26. AMMONITES HYPERBOLICUS, Leckenby (Simpson, MS.).
Pl. II. fig. 4*a*, 4*b*.

This, on the contrary, is so much thicker than *Am. Chamusseti* as to be nearly globular. The outer whorl entirely envelopes the umbilicus; and the keel, which is not crenulated, is nearly obsolete.

27. AMMONITES GLABELLUS, Leckenby (Bean, MS.). Pl. II. fig. 5*a*–5*c*.

Discoid; sides of the whorl smooth, or nearly so, having only faint distant undulations, which are most conspicuous towards the keel: back, a sharp keel becoming rapidly obtuse with age; aperture elliptical, deeply indented by the succeeding whorl.

*Locality*. Scarborough Castle Rock.

28. AMMONITES CONTERMINUS, Bean, MS.

Discoid; whorls flatted, their inner margin perpendicular, their outer margins rounded towards the back: ribs sigmoidal, bifurcating in the middle of the whorl, and terminating near the outer margin; keel slightly elevated; aperture ovate, slightly indented by the succeeding whorl.

*Localities*. Scarborough Castle Rock, and near Gristhorpe Bay.

29. AMMONITES BIPARTITUS, Zieten.

*Locality*. Scarborough Castle Rock.

30. AMMONITES BAUGIERI, D'Orbigny.

*Locality*. Near Gristhorpe Bay only.

The last two species agree exactly with the descriptions and figures of D'Orbigny.

PLEUROTOMARIA ARENOSA, Leckenby (Bean, MS.). Pl. III. fig. 1*a*, 1*b*.
*Trochus arenosus*, Bean, MS.

Shell conical, imperforate?; whorls (6 or 7) flat, transversely and longitudinally ribbed, giving the shell a somewhat decussated appearance; at the lower portion of each whorl is a prominent band, formed of four strongly undulating nodular ridges, then two finer lines; these are succeeded by a smooth space, along the centre of which is the raised sutural band, somewhat crenulated; the remainder of the whorl occupied by eight or nine transverse wavy lines, crossed by oblique longitudinal finer ones, which are more prominent at distant intervals.

This species is closely allied to the *Pleurotomaria Galathea*, D'Orb. Pal. Franç. Terr. Jurassique, pl. 423. fig. 1-4.

*Locality*. Castle Rock, Scarborough.

PLEUROTOMARIA STRIATA, Leckenby (Bean, MS.). Pl. III. fig. 2*a*, 2*b*.
*Cirrus striatus*, Bean, MS.

Shell depressed, umbilicate?; whorls four, tabulated; keel slightly prominent, transversely ridged and crossed by numerous very fine oblique, irregularly undulating, raised lines, which pass uninterruptedly over the keel.

*Locality*. Castle Rock, Scarborough.

PATELLA ? GRAPHICA, Leckenby (Bean, MS.). Pl. III. fig. 3*a*, 3*b*.

Shell oval, obliquely conical; apex very excentric, and marked by many radiating impressed lines, which become somewhat obsolete towards the margin.

*Locality*. Castle Rock, Scarborough.

CERITHIUM ABBREVIATUM, sp. nov. Pl. III. fig. 12.

Shell short, turreted, with about nine flattened volutions, and the suture distinct; height of the whorls only half their breadth, each with four rows of encircling costæ, and eight or nine elevated perpendicular spinose ribs; the ribs pass across the volutions obliquely from right to left; each rib has four large, prominent, obtuse, but rather irregular and unequal tubercles, which give to the shell a rugged aspect. Length about 7 lines, of which one-fourth is occupied by the aperture.

*Locality*. The Castle Rock, Scarborough.

CERITHIUM CULLENI, sp. nov. Pl. III. fig. 13.

Shell turreted, volutions eleven or twelve, compressed, somewhat angular at their junctions; their height is three-fourths the breadth, each having four rows of transverse costæ, undulated by the twelve or thirteen longitudinal ribs, and which run perpendicularly from the base to the apex.

It differs from *C. muricatum*, to which it bears some resemblance, in its less rapid volutional increase, and in the smaller number of its longitudinal costæ, which are also quite straight, and not bent in the middle of each volution, as in that species.

Named after Mr. Peter Cullen, the indefatigable collector of fossils at Scarborough.

*Locality*. The Castle Rock, Scarborough.

CHEMNITZIA LINEATA, sp. nov. Pl. III. fig. 14.

Shell turreted, smooth to the naked eye; whorls eight or nine, moderately convex, most delicately striated transversely, with an elevated line at the top of each whorl; the sutural line is well defined. Length $\frac{1}{2}$ in.

CUCULLÆA CLATHRATA, sp. nov. Pl. III. fig. 4.

Shell elongate, very inequilateral; beaks prominent, anteriorly rounded, posteriorly impressed, truncated, and obtusely carinated; surface ornamented with numerous close small ribs (larger on the posterior margin) crossed by the numerous concentric lines, giving the shell a very decussated appearance. The anterior margin is not marked with the more prominent ridge, usually occurring in this genus.

*Locality*. The Castle Rock, Scarborough. This species also occurs in the Cornbrash below.

CUCULLÆA MINIMA, sp. nov. Pl. III. fig. 5.

Shell small, somewhat quadrate, ventricose, nearly equilateral, slightly carinated posteriorly, marked by numerous concentric ridges, finely decussated by many radiating impressed lines, giving the surface a punctated appearance.

*Locality.* The Castle Rock, Scarborough.

SOLEMYA WOODWARDIANA, sp. nov. Pl. III. fig. 7.

Shell transverse, elliptical, compressed posteriorly, short and rounded anteriorly; the ribs (eight or nine) on the posterior side prominent and granulated, those on the anterior side somewhat obsolete.

This interesting species, of a comparatively rare recent genus, is closely allied to the *Solemya Voltzii*, Rœmer (Verst. Nord. Oolithen-Gebirges, pl. 19. f. 20).

*Locality.* North side of the Castle Rock, Scarborough.

UNICARDIUM SULCATUM, Leckenby (Bean, MS.). Pl. III. fig. 11.

Shell ovate, ventricose, inequilateral; anterior and posterior sides rounded, concentrically but irregularly sulcated; umbones prominent.

*Locality.* South side of the Castle Rock, Scarborough.

CARDIUM COGNATUM, Phillips. Pl. III. fig. 8*a*, 8*b*.

We have figured a more perfect example than the type-specimen of Professor Phillips, showing the ornamentation of the posterior area. It was only by comparison with the original specimen that the species could be identified.

CARDIUM CRAWFORDII, sp. nov. Pl. III. fig. 9*a*, 9*b*.

Shell subequilateral, ventricose, compressed towards the margins; umbones prominent; surface smooth, or with very faint concentric striæ; the posterior area ornamented with about fifteen longitudinal ribs; the middle ribs are the largest and more apart, and appear somewhat scabrous; they disappear or become quite faint before reaching the posterior edge; there is no definite ridge at the junction of the posterior area with the dorsal surface; the posterior margin is slightly angulated, and its junction with the ventral margin well defined; this, and the anterior margin, are gently rounded.

Named after Mr. W. B. Crawford, to whose exertions I am indebted for many fine specimens.

*Locality.* The north side of the Castle Rock, Scarborough.

ISOCARDIA (?) CLARISSIMA, Leckenby (Bean, MS.). Pl. III. fig. 10*a*, 10*b*.

Shell subtrigonal; umbones prominent and incurved; the surface smooth where the shell remains; posterior area flattened, its junction with the dorsal defined by a ridge; anterior margin slightly produced and gently rounded; posterior margin angulated.

*Locality.* The north side of the Castle Rock, Scarborough.

P.S. I am indebted to Professor Morris for much valuable assistance in the identification of species, and in preparing the descriptions of several of the new ones.—J. L.

## DESCRIPTION OF PLATES I., II., III.

*Illustrating some Fossils of the Kelloway Rock of Yorkshire.*

### Plate I.

Fig. 1*a*. Ammonites Gowerianus, *Sow.*; nat. size. (A portion entire.)
1*b*. ——— ———. At a more advanced period of growth; nat. size.
1*c*. ——— ———. Shape of the aperture.
1*d*. ——— ———. Suture.
2. Am. reversus, *Leckenby* (*Simpson, MS.*); nat. size.
3*a*. Am. Vertumnus, *Leckenby* (*Bean, MS.*); nat. size.
3*b*. ——— ———. Outline of front view.
4*a*. Am. poculum, *Leckenby* (*Bean, MS.*); nat. size. (A portion entire.)
4*b*. ——— ———. Older and thicker form; nat. size.
4*c*. ——— ———. Suture.

### Plate II.

Fig. 1. Ammonites placenta, *Leckenby* (*Bean, MS.*); nat. size.
2*a*. Am. alligatus, *Leckenby* (*Bean, MS.*); nat. size.
2*b*. ——— ———.
3*a*. Am. putealis, *Leckenby* (*Bean, MS.*); nat. size.
3*b*. ——— ———. Form of the aperture. In the specimen here figured, the siphuncle is not symmetrically placed, the dorsal lobe being on the left of the keel.
3*c*. ——— ———. Suture.
4*a*. Am. hyperbolicus, *Leckenby* (*Simpson, MS.*), side view; half nat. size.
4*b*. ——— ———. Front view, showing aperture.
5*a*. Am. glabellus, *Leckenby* (*Bean, MS.*).
5*b*. ——— ———. Shape of the aperture.
5*c*. ——— ———. Suture.

### Plate III.

Fig. 1*a*. Pleurotomaria arenosa, *Leckenby* (*Bean, MS.*); nat. size.
1*b*. ——— ———. Enlarged view of part of a suture and ornament.
2*a*. Pl. striata, *Leckenby* (*Bean, MS.*). Upper view of spire.
2*b*. ——— ———. Side view.
3*a*. Patella? graphica, *Leckenby* (*Bean, MS.*); nat. size. Upper view.
3*b*. ——— ———. Side view.
4. Cuculæa clathrata, *Leckenby*; two thirds of nat. size.
5. Cucullæa minima, *Leckenby*; nat. size.
6. Anatina versicostata, *Buvignier*; nat. size.
7. Solemya Woodwardiana, *Leckenby*; nat. size.
8*a*. Cardium cognatum, *Phillips*; nat. size. View of left valve.
8*b*. ——— ———. View of the hinge-area.
9*a*. Cardium Crawfordii, *Leckenby*; nat. size.
9*b*. ——— ———. View of the hinge-area.
10*a*. Isocardia? clarissima, *Leckenby* (*Bean, MS.*); nat. size.
10*b*. ——— ———. View of the hinge-area.
11. Unicardium sulcatum, *Leckenby* (*Bean, MS.*); nat. size.
12. Cerithium abbreviatum, *Leckenby*; enlarged.
13. Cerithium Culleni, *Leckenby*; enlarged.
14. Chemnitzia lineata, *Leckenby*; enlarged.

Ammonites Gowerianus (p. 9). *Localities.* Red Cliff and the south side of Scarborough Castle Rock.

Ammonites hyperbolicus (p. 12). *Locality.* Red Cliff.

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### 3. *On the* Rock-basins *in the* Granite *of the* Dartmoor District, Devonshire. By G. Wareing Ormerod, Esq., M.A., F.G.S.

[Abstract.]

In this Memoir the origin of Rock-basins in the Granite of Dartmoor and its vicinity is alone considered; and it is not attempted to draw therefrom any law as to the manner of the formation of similar basins elsewhere. It has been here attempted to notice all the hollows known as Rock-basins in this district; and in the table appended, particulars of these and of the chief Tors are contained. A few localities it has not been in the power of the Author to visit; and the description is in those cases taken from the observations of others: doubtless also some basins have escaped notice, but a considerable number have been examined, and the particulars noted on the same system, so as to give an opportunity of comparison. The situation of Dartmoor is too well known to need description. The geological formation is entirely of granitic rocks. From near the same point in the northerly part of the moor the Tavy flows westerly and the Teign easterly: to the north of these rivers very few rock-basins exist, and those too are in the immediate vicinity of these rivers. To the south of a line formed by the Plymouth and Dartmoor railway and the River Dart, it is believed rock-basins have not been found; but this last district has not been completely examined by the Author. The part of Dartmoor, therefore, in which the rock-basins exist is a central belt, which occupies about one-third of the area of the moor. The particulars of the various basins are set out in a tabular form; it will therefore be only needful to notice some of the most important. The only basin to the north of the Tavy with which the Author is acquainted is at Hare Tor. To the south of the Tavy Fur Tor is the highest point of Dartmoor, being 2000 feet above sea-level. The rocks composing this Tor are scattered over a considerable area, are much weathered, for the most part broken and low, and forming ledges, but occasionally rising into large masses. The granite is generally porphyritic, being coarse-grained with large felspar, and has a laminated structure. On this Tor there are three basins. Between the Tavy and Wallcombe River, Roose or Roll's Tor, Staple Tor, Vixen Tor, and Pew Tor are worthy of notice: the two last mentioned are particularly described in Bray's Tamar and Tavy. Between Wallcombe River and the East Webber, Mistor is the most conspicuous and known Tor; it is situate on an insulated hill 1760 feet above sea-level. The Tor consists of long, narrow, low cliffs, which rise on the eastern and western sides of the summit of the hill (that on the eastern side being the most lofty and extensive), ranging nearly from north to south. The space between these is occupied by detached masses varying in size. The granite is laminated and much weathered at the junctions of the beds and of the perpendicular planes, and there are occasionally overhanging beds. "Mistor Pan" is the only basin on this Tor; it is situate near the northerly end of the eastern range on the summit. This basin has been supposed to be artificially formed, and is described in

Rowe's Dartmoor and Bray's Tamar and Tavy. The sides are nearly perpendicular, leaning slightly back. At the south-easterly side the highest bed of rock projects slightly, and under this a hole reaches through to the eastern side of the Tor about two inches above the bottom of the pan. The only other places where similar perforations have been observed are at Fur Tor and Willistone Rocks. From the northerly side, a lip or channel runs for about five inches in a northerly direction, and then irregularly; at the basin it is about five inches wide, and there reaches nearly to the bottom of the basin. The diameter from N. to S. is 36 inches, from E. to W. 35 inches, and the longest diameter from N. to S. The depth (at the lip) on the north side is 4 inches, on the easterly 6 inches, on the southerly 5 inches, and on the westerly 6 inches. The bottom is nearly level, but slopes slightly towards the centre, where it is about half an inch deeper than at the sides. The bottom was covered with small sharp gravel, consisting chiefly of felspar and quartz, formed by the disintegration of the granite.

With the exception of the perforation, and that a lip is not of very frequent occurrence, the above description is also applicable, the dimensions being altered, to nearly every rock-basin with a flat bottom; and there seems to be no reason for considering the origin of this basin different from that of the other basins. On Bell Tor, to the east of the East Webber, there is a large basin that well exhibits the atmospheric action on the granite. Hounter Tor in the same locality is one of the grandest and most picturesque Tors of the Dartmoor district. No rock-basins have been observed there, or at the rocks by Bowerman's Nose or Manaton Tors. The remaining basins are mostly classed with those lying within the watershed of the Teign. At a rapid, a short distance below the bridge at Teignhead, "pot-holes" are in the course of formation: these will be noticed hereafter. About a mile and a half lower down on the left bank of the river is the well-known "Tolmen" or Holed Stone: the perforation is about three feet in diameter, and 2 feet 8 inches in depth, and passes obliquely through the stone. This rock is not *in situ*, and rests on other transported blocks at a rapid where the Teign has worked its way between the rocks, causing a gradual lowering of the level of its bed; so that the surface of the Tolmen is now only covered by the water in very heavy floods. There are portions of other "pot-holes" on this rock; and the origin may, with little if any hesitation, be ascribed to the same cause as that which is now forming the "pot-holes" just mentioned. About three-quarters of a mile to the south of this spot is Castor or Kestor Rock, a large insulated Tor about 1417 feet above sea-level. The summit of this Tor consists of three bosses, rising slightly above a level central platform; the rock is weathered and rounded; and the beds, with the exception of a bed of elvan, are not of fine or compact granite. The directions of the perpendicular joints are W. by S. to E. by N., N. by W. to S. by E., and N.W. by N. to S.E. by S. On this Tor, besides some hollows which have not been regarded as "basins," there are four basins on the northerly boss, three on the central platform, and two on the southerly boss; and of these the particulars are given in the Table. One large basin on the central platform will require description. This basin was discovered by the Author on 17th Sept., 1856. The opening at the top, as marked by the line to which water stands when it is full, is oval, measuring 8 feet from N. to S. and 6 feet 8 inches from E. to W. A few inches below this level the basin is nearly circular; the diameter half way down is 50 inches; at the bottom 24 inches: the perpendicular depth is 31 inches. The bottom is flat, rounding up at the edges to the sides, which curve outwards in the form of the mouth of a trumpet, and two indentations, caused by decay, run round the basin. The bottom and sides up to the lowest indentation (12 inches) were covered with dead Sphagnum, which formed a compact mass, adhering so closely as to have taken a cast of the granite; between these there were not any stones, nor the small fragments of quartz and felspar usually found in rock-basins. At the bottom of the basin, above the Sphagnum, there was a thin layer of fine black peaty soil, and the remaining contents—evidently of a later date—consisted of, first, a compact mass of fine dark sand and gravel 6 inches in thickness, and above this a brown peaty soil containing fragments of quartz and felspar, which filled the basin to the level, and the whole was covered over by a thick growth of heath. This arrangement is such as would arise from a maceration of peat exposed to the wet and storms that occur at this spot. Attention having been attracted by the opening of this basin, the Author has received information derived from an old "Moorman," which leads him to suppose that the basin was filled with peat between 100 and 150 years ago to prevent accidents to sheep. This basin has not been empty of water since it was opened in September, 1856. A short distance below the junction of the North and South Teign Rivers, at Legh Bridge, on a spur projecting on the right hand of the valley, a rock-basin is found on the top of a large transported block of granite known as the Puckie stone. This basin is irregular in shape, and measures 40 inches from N. to S. and 43 inches from E. to W. The longest diameter is nearly N.W. to S.E., 58 inches; the sides are nearly upright, and from 2 to 5 inches high; the bottom is nearly flat, but rough from the projecting felspar; it was covered with fine sand composed of disintegrated granite. The rock is broken through the centre, and the fracture must have taken place since it was placed in its present position. The River Teign runs in a hollow about 80 feet below this stone; and it seems very probable that the spur on which this stone is deposited, formed part of the lower bank of a small lake extending upwards to the commencement of a narrow gorge above Gidley Park. On Middleton (or Meldon) hill, above Chagford, there are several basins. In Rushford woods, near that town, to the north of the Teign, there is a basin called "The Punch Bowl," on an insulated piece of rising ground known as "The Bowling Green," and a small irregular basin is formed on the Tors at Sandsgate near the same locality. At Wilistone, as before mentioned, there is a perforation in the side of a basin. Near Bridford, at Hell Tor, we find several basins. A cleft passes through the centre of this Tor running from E. by N. to W. by S.: this direction, and from N.E. to S.W., are the directions of the perpendicular joints. The granite is laminated and coarse with the exception of a bed of very compact crystalline granite running nearly horizontally about 8 feet below the summit of the Tor. On the southern part of the Tor there are 4 perfect and 1 imperfect basins, on the northern part 5 basins, and of the last, one is the largest basin that the Author has seen in this district. This basin communicates with the northerly side of the cleft; in shape it approaches to that of a large caldron, but is not very regular in form; it measures about 12 feet from N. to S. and 11 feet from E. to W.: the height from the centre of the bottom to the level of the top of the sides is about 5 feet; the height from a cleft (5 inches wide) at the bottom of the broken southerly side is about 7 feet; this cleft extends across the basin, and reaches 4 feet beyond its edge in a northerly direction; and on the easterly and westerly sides hollows open into this basin. Nearly adjoining, there is a large oval hollow measuring about 10 feet from N. to S. and 20 feet from E. to W.: at the N.N.E. the side is broken away, but the average height of the sides above the grass is about 24 inches: the depth to this rock below the turf in the centre is 10 inches: this hollow has not been included in the list of basins, as doubts may be entertained as to its origin. On the hill to the left of the valley that extends from Moreton Hampstead to Bovey there are two basins worthy of note; one at Ingstone, on account of its size; the other at Bullaton Rock, as being in a small transported block resting on a large rock. To the north of the Teign, the most remarkable Tors are Wattern, Wild, Belstone, and Yes (2050 feet above sea-level, the highest point of ground in Devon); on these no basins exist.

The Table appended to this paper (p. 24) contains the names of localities examined, of which the following is a summary:—

| Height above sea-level. | Number of Tors examined. | Tors without basins. | Tors with basins. | Number of basins. |
|---|---|---|---|---|
| 2000 feet and upwards | 2 | 1 | 1 | 3 |
| 1800 ,, and under 2000 | 1 | 1 | 0 | 0 |
| 1600 ,, ,, ,, 1800 | 15 | 13 | 2 | 2 |
| 1400 ,, ,, ,, 1600 | 14 | 5 | 9 | 23 |
| 1200 ,, ,, ,, 1400 | 21 | 10 | 11 | 21 |
| 1000 ,, ,, ,, 1200 | 4 | 0 | 4 | 12 |
| 800 ,, ,, ,, 1000 | 5 | 0 | 5 | 6 |
| 600 ,, ,, ,, 800 | 4 | 0 | 4 | 4 |
| Below 600 feet or height uncertain | 7 | 6 | 1 | 4 |
| | 73 | 36 | 37 | 75 |

In the following comparison the basins that have not been examined by the Author, imperfect basins, and four that far exceed the average size (viz. at Hell Tor, Kestor, Ingstone, and Bell Tor) are not included. The 35 basins which will be compared are scattered over the whole area of Dartmoor, with the exception of part of the western and southern edges which the Author has not personally examined. The diameters vary from 11 inches by 10 inches to 42 inches by 54; the depths from 2 inches to 9 inches,—the average depth being $4\frac{1}{7}$ inches; 8 are saucer-shaped, and 27 have the bottom flat and sides perpendicular, or slightly sloping. The following Table shows the surface-diameter, depth, and description of bottom of the 6 smallest and 6 largest of the 35 basins. It will be observed that the increase of depth is very small, and not in proportion to the increase of the diameter, and that 5 out of the 8 saucer-shaped are in the list of the 6 smallest basins.

SIX SMALLEST BASINS.

| Diameter. | Depth. | Bottom. |
|---|---|---|
| 10×11 | 2 ins. | Flat. |
| 12×15 | 2 " | Saucer. |
| 12×18 | 3 " | do. |
| 13×14 | $2\frac{1}{2}$ " | do. |
| 14×18 | 6 " | do. |
| 14×21 | 7 " | do. |

SIX LARGEST BASINS.

| Diameter. | Depth. | Bottom. |
|---|---|---|
| 39×42 | 5 ins. | Flat. |
| 40×42 | 5 " | do. |
| 40×43 | 3 " | do. |
| 40×48 | 7 " | do. |
| 41×46 | 5 " | do. |
| 42×54 | 5 " | do. |

TABLE OF DEPTHS OF BASINS.

| | | | | |
|---|---|---|---|---|
| 6 basins | 2 | inches | deep. |
| 1 | " | $2\frac{1}{2}$ | " | " |
| 10 | " | 3 | " | " |
| 3 | " | 4 | " | " |
| 1 | " | $4\frac{1}{2}$ | " | " |
| 6 | " | 5 | " | " |
| 4 | " | 6 | " | " |
| 3 | " | 7 | " | " |
| 1 | " | 9 | " | " |

TABLE OF DIRECTION OF LONGEST DIAMETER.

| | | | | |
|---|---|---|---|---|
| In | 12 | basins | from | N. to S. |
| " | 3 | " | " | N.N.W.—S.S.E. |
| " | 6 | " | " | N.W.—S.E. |
| " | 4 | " | " | N.W. by W.—S.E. by E. |
| " | 5 | " | " | W.—E. |
| " | 3 | " | " | W.S.W.—E.N.E. |
| " | 2 | " | " | S.W.—N.E. |

With respect to the origin of the Rock-basins—First, it is not thought needful to enter upon the question whether they were formed artificially by the Druids, or by others, as it is believed that few if any now entertain either opinion. Secondly, as regards the formation of hollows by the sea or water in motion, those causes probably may be considered as similar, and the following account of the "pot-holes" in the granite at the rapid before mentioned near Teignhead will illustrate this point:—At the top of this rapid the Teign, when flooded rushes, along a nearly level surface of rock.

On this, there are several long, oval, concave, shallow hollows, pointing up and down stream; the sweep of the water carries the stones along and over these, the grinding action adding apparently to the length in a far greater degree than the breadth. The measures of six hollows at this place are 7 inches by 16 in diameter, and 3 inches deep; 8 inches by 12 in diameter, and 1 inch deep; 9 inches by 14 in diameter, and 1 inch deep; 9 inches by 18 in diameter, and 4 inches deep; 10 inches by 12 in diameter, and 2 inches deep; 12 inches by 27 in diameter, and 3 inches deep. The river in floods, after passing over this rock, falls nearly perpendicularly about 6 feet into some "pot-holes." One of these nearly circular is 23 inches by 24 in diameter, and 15 inches in depth, and at the bottom there are large round stones; the sides are nearly upright, curving in at the bottom, which appears to be concave; but, in consequence of the quantity of water at the time when the examination was made, this point was not clear. Another is 12 inches by 10 in diameter, and more than 26 inches in depth. This "pot-hole" enlarges a few inches above the bottom, having probably penetrated a softer bed of granite, and the lower part is nearly filled with round stones; for the same reason as above mentioned the bottom could not be examined. In both these cases the direct downward action of the stream would give very considerable motion to the stones. On the adjoining but more open rock on this lower level, exposed to the horizontal sweep of the flood, but not so directly as at the top of the rapid, the hollows are again of the long oval shape, but the longitudinal section is different. The rush of the water not being here so violent as above, stones remain at the upper ends of the hollows, being there protected against the current; and, there rotating, wear deep holes, which on the side up stream are nearly perpendicular, and on the opposite side slope gradually away to the lower end of the hollow. If the "basins" are compared with these "pot-holes," we find the majority to be here concave and irregular; there to have the bottoms flat and regular with upright sides; here in those having upright sides the depth is excessive in proportion to the diameter, there it is the contrary.

Sir Henry De la Beche, in a note on the 'Report on Cornwall, Devon, and West Somerset' (p. 452), writes:—"Dr. M'Culloch has suggested that the friction of the quartz and felspar fragments not unfrequently found in rock-basins may have contributed to deepen them. As we have often observed these fragments in motion during high winds, both when the basins were dry, or a small quantity of water in them, we are inclined to believe that this may be the case." These fragments occur in most basins; in some, as shown in the table, the bottom is covered by them. Rolled stones similar to those which occur in the "pot-holes" have not been found by the Author in any basin, but the contents generally consist of a small *angular* fragment of quartz and felspar, as above mentioned, and schorl, which sometimes, as shown in the following table, cover the bottom of the basin. Small lumps of granite occasionally are found not rolled, but that have apparently fallen in where the sides are much weathered and falling to decay. Although in the habit of inspecting the basins in every state of the weather, from the mildest breeze to the heaviest storm, the Author had never seen these particles blown about in the water in the basins having the bottoms flat and sides upright, and had only seen them moved in shallow concave basins when dry, or when a heavy gale had blown them out together with the water. The cause suggested by Dr. M'Culloch could not affect the deep basins, as in those cases the particles would be undisturbed by motion of the water from wind. These small fragments, however, throw some light on the manner of the formation of the rock-basins. The granite of the Dartmoor district is in a great measure porphyritic; it is for the most part of a large coarse grain, and schorl in variable proportions frequently occurs; globular nodules varying from an inch to upwards of a foot in diameter, often occur. These vary much; sometimes they are harder than the adjoining rock, sometimes scarcely coherent, and soon falling away on exposure to the weather. Along the belt where the basins exist, the granite is for the most part more liable to decomposition than at the harder and more crystalline Tors. This is shown by the many rounded Tors, and every roadside cutting shows the rapidity of the decay. The division of the granite into tabular sheets of rock of irregular thickness, causing the appearance of stratification, is common to all the granite of this district. In irregularities on the surface of the granite, and in hollows, very probably in many cases caused by the nodules above noticed, water lodges and penetrates the porous granite, and the decay thus commenced will gradually enlarge the cavity to a basin. During the inclement part of the year these basins are full of water, that during part of the time often rapidly alternating with ice. When the warm weather comes on, the water evaporates, and the basins are dried up; from the frequent showers there is, then, a constant change between the rock being saturated with wet, and being warm and dry. The gradual action of the water is very perceptible; when it has evaporated, the stone up to the water-line is left a lighter shade than the adjoining rock; the felspar-crystals, instead of presenting their usual appearance, are dull and full of minute cracks, and appear as if about to fall into small fragments similar to those found in the basins; the action of the water is evident to the eye though not easily described. An unbroken face of granite resists the weather more powerfully than the rock does when it is broken or penetrated; in those cases the water soaks into the granite, and thus renders it more easily acted upon by the alternations of heat and cold, wet and dryness. Such action, when once commenced, will continue until checked by the unbroken face of a parting which will limit the extension either perpendicularly or horizontally. The tabular formation of the granite is probably the cause of the frequent occurrence of the basins with flat bottoms. The gradual decay thus acting from a centre will cause the nearly circular and oval forms that so many of the basins present,—the variation from that shape being probably caused by a difference in the structure of the granite. The eye will in a short period discriminate between the Tors where basins would probably be found or not. First, rock-basins are scarcely ever found where it is the character of the Tor to have the perpendicular joints clearly developed,—the angles, where exposed, being only slightly weathered, and the horizontal beds, if thick, standing out with well-defined edges and ends, if thin, with sharp projecting edges, giving to the side a serrated appearance. When, on the contrary, the Tor is rounded, the sides sloping or smooth, projecting beds not frequent or bold, and such beds as do project for the most part rounded at the edges, rock-basins will very frequently be found. For the above reasons, the Author considered that in this district the rock-basins were caused by atmospheric action, that power working gently but surely upon the rock, and equally forming every description of basin, be it large or small, deep or shallow; this the rotation of pebbles, he considered, could not do.

The direction of the longest diameter is shown by the preceding Table (p. 20) to be in nearly one-third of the cases from N. to S., and in all but 5 out of the 35 cases to be from the north-westerly to the south-easterly quarter: the cause of this the Author has not been able to discover. Although the direction of the longest diameters is in the greater number of instances towards the same points, between which the perpendicular joints of the granite of Dartmoor generally range, he had not found that there was any connexion between them; the direction of the longest diameters rarely corresponding with that of either the main or cross joints on the same Tors; neither do the directions of the basins on the same Tor always agree. The most violent storms on Dartmoor come from between W. and S.W.; although occasionally heavy gales occur from the S.E., the winds from between the S. and E. are generally mild, and those between the N. and N.W. are not of frequent occurrence. The direction, therefore, of the longest diameter cannot be assigned to the action of the strongest or most prevalent winds. The Author, in conclusion, acknowledges his obligations to Dr. Croker, F.G.S., for his aid in pointing out the localities of certain basins.

*Table of Tors and Rock-basins*

*North of the*

| Name of Tor. | Direction of Perpendicular Joints. | If Basin and Shape of Basin. | Diameters N. & S. | Diameters E. & W. |
|---|---|---|---|---|
| Hare Tor............... | ......... | Oval. | ... | ... |
| | | *Between the Rivers* | | |
| Fur Tor ............... | ......... | ......... | ... | ... |
| " ............... | ......... | And two small basins. | ... | ... |
| Lints Tor ............... | ......... | None. | ... | ... |
| Rolls Tor ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| " ............... | ......... | And several imperfect. | ... | ... |
| Staple Tor ............... | ......... | ......... | ... | ... |
| " ............... | ......... | And one shallow. | ... | ... |
| Cocks Tor ............... | ......... | None. | ... | ... |
| Vixen Tor ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| Over Tor ............... | ......... | ......... | ... | ... |
| Pew Tor ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| " ............... | ......... | ......... | ... | ... |
| | | *Between the Rivers* | | |
| Mistor ............... | ......... | Oval. | 36 | 35 |
| Baredown Tor ............... | ......... | None. | ... | ... |
| Lower White Tor ............... | N. by W. to S. by E. | " | ... | ... |
| Higher White Tor............... | N. by E. to S. by W. | " | ... | ... |
| Longaford Tor ............... | N. by E. to S. by W. | Circular. | ... | ... |
| Bee Tor ............... | ......... | Oval. | 23 | 24 |
| Little Bee Tor ............... | N. by E. to S. by W. | " | 20 | 23 |
| " | ......... | And three small Basins. | ... | ... |
| Crockern Tor............... | ......... | None. | ... | ... |
| Arch Tor ............... | ......... | " | ... | ... |
| Crip Tor ............... | ......... | " | ... | ... |
| King Tor ............... | ......... | " | ... | ... |
| Hessary Tor ............... | ......... | " | ... | ... |
| Bellever Tor ............... | ......... | " | ... | ... |
| Laugh Tor ............... | ......... | " | ... | ... |

*examined in the District of Dartmoor.*

*River Tavy.*

| of Basins in inches. | | Average Height of Sides. | Shape of Bottom. | Central Depth of Saucer. | Contents. | Observer. |
|---|---|---|---|---|---|---|
| Greatest Direction. | Greatest Amount. | | | | | |
| ... | ... | ... | ......... | ...... | ...... | Bray. |

*Tavy and Wallcombe.*

| | | | | | | |
|---|---|---|---|---|---|---|
| ... | 30 | 8 | ......... | ...... | ...... | Bray. |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | Ormerod. |
| ... | 12 | ... | ......... | ...... | ...... | Bray. |
| ... | ... | 15 | ......... | ...... | ...... | " |
| ... | 24×18 | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | 18 | 12 | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | 48×38 | 8 | ......... | ...... | ...... | " |
| ... | 48 | 14 | ......... | ...... | ...... | " |
| ... | 18 | 9 | ......... | ...... | ...... | " |
| ... | 36 | 8 | ......... | ...... | ...... | " |
| ... | 24 | ... | ......... | ...... | ...... | " |
| ... | 30×21 | 6 | ......... | ...... | ...... | " |
| ... | 36×24 | 10 | Flat | ...... | ...... | " |
| ... | 24 | 11 | ......... | ...... | ...... | " |
| ... | 36 | 13 | ......... | ...... | ...... | " |

*Wallcombe and East Dart.*

| | | | | | | |
|---|---|---|---|---|---|---|
| N. and S. | 36 | 5 | Level. | ...... | Angular fragments of quartz and felspar. | Ormerod. |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | 18 | ... | Saucer. | Shallow. | ...... | " |
| N.W. to S.E. | 26 | 3 | Flat. | ...... | As at Mistor. | " |
| N.W. by W. to S.E. by E. | 23 | 3 | " | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | Bray. |
| ... | ... | ... | ......... | ...... | ...... | " |
| ... | ... | ... | ......... | ...... | ...... | Rowe. |
| ... | ... | ... | ......... | ...... | ...... | " |

Table (*continued*).

*Between the Rivers*

| Name of Tor. | Direction of Perpendicular Joints. | If Basin and Shape of Basin. | Diameters N. & S. | Diameters E. & W. |
|---|---|---|---|---|
| Warren Tor | ......... | None. | ... | ... |
| Hookner Tor | ......... | " | ... | ... |
| North Tor | ......... | " | ... | ... |
| Yar Tor | ......... | " | ... | ... |
| Quarniam Tor | N.W. by W. to S.E. by E., S. by W. to N. by E. | " | ... | ... |
| Mill Tor | ......... | " | ... | ... |
| " | ......... | " | ... | ... |
| " | ......... | " | ... | ... |
| " | ......... | " | ... | ... |

*Between East Webber*

| Name of Tor. | Direction of Perpendicular Joints. | If Basin and Shape of Basin. | Diameters N. & S. | Diameters E. & W. |
|---|---|---|---|---|
| East Down | N.W. by W. to S.E. by S. N.E. by E. to S.W. by N. | One small basin. | ... | ... |
| Cribbern Tor | ......... | Irregular. | 29 | 18 |
| Honey Bag Tor | S.W. and N.E. | Oval. | 29 | 20 |
| " | ......... | " | 18 | 12 |
| Chinkwell Rock | ......... | None. | ... | ... |
| Bell Tor | ......... | Oblong. | 20 | 26 |
| " | ......... | Irregular. | 36 | 24 |
| " | ......... | Oval and broken. | 36 | 30 |
| Charbetor | ......... | None. ? | ... | ... |
| Hounter Tor | E. to W., N. by W. to S. by E. | None. | ... | ... |
| Saddle Tor | ......... | Oval. | 20 | 15 |
| Hey Tor | N.W. to S.E., N.W. by N. to S.E. by S., E. to W. | " | 28 | 34 |
| " | ......... | And two imperfect. | ... | ... |
| Leighn Tor | ......... | Oval. | ... | ... |
| Bowerman's Nose | ......... | None. | ... | ... |
| Manaton Tor | ......... | " | ... | ... |

*Within the Watershed of the*

| Name of Tor. | Direction of Perpendicular Joints. | If Basin and Shape of Basin. | Diameters N. & S. | Diameters E. & W. |
|---|---|---|---|---|
| Siddaford Tor | ......... | None. | ... | ... |
| Kestor | W. by S. to E. by N. | Oblong. | 14 | 24 |
| " | N. by W. to S. by E. N.W. by N. to S.E. by S. | Oval. | " | 13 |
| " | ......... | " | 21 | 14 |
| " | ......... | " | 30 | 28 |
| " | ......... | Irregular. | 24 | 26 |
| " | ......... | Oval. | 34 | 34 |

*East Dart and East Webber.*

| of Basins in inches. Greatest Direction. | Amount. | Average Height of Sides. | Shape of Bottom. | Central Depth of Saucer. | Contents. | Observer. |
|---|---|---|---|---|---|---|
| ... | ... | ... | ......... | ...... | ...... | Ormerod. |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | 32 | ... | ......... | ...... | ...... | Polwhele. |
| ... | 20 | ... | ......... | ...... | ...... | ,, |
| ... | 24 | ... | ......... | ...... | ...... | ,, |
| ... | 12 | ... | ......... | ...... | ...... | ,, |

*and Wray Brook.*

| | | | | | | |
|---|---|---|---|---|---|---|
| ... | ... | ... | ......... | ...... | ...... | Ormerod. |
| N. and S. | 29 | 3 | Flat. | ...... | As Mistor. | ,, |
| ,, | 29 | 9 | ,, | ...... | ...... | ,, |
| ,, | 18 | ... | Saucer. | 3 | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| N.N.W. and S.S.E. | 37 | 7 | Flat. | ...... | As Mistor. | ,, |
| N. and S. | 36 | 4 | ,, | ...... | ...... | ,, |
| ... | ... | 24 | Caldron. | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | 20 | ... | Saucer. | Shallow. | As Mistor. | ,, |
| E. and W. | 34 | 3 | Nearly flat. | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| N.N.W. S.S.E. | 29 | ... | Saucer. | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |
| ... | ... | ... | ......... | ...... | ...... | ,, |

*South Bank of the River Teign.*

| | | | | | | |
|---|---|---|---|---|---|---|
| ... | ... | ... | ......... | ...... | ...... | Ormerod. |
| W.S.W. and E.N.E. | ... | 4½ | Flat. | ...... | ...... | ,, |
| N.W. by W. and S.E. by E. | 14 | ... | Saucer. | 2½ | ...... | ,, |
| N. and S. | 21 | 7 | ,, | 1½ | ...... | ,, |
| W.S.W. and E.N.E. | 32 | 6 | Flat. | ...... | ...... | ,, |
| N.W. by W. S.E. by E. | 28 | 2 | ,, | ...... | ...... | ,, |
| ,, | 36 | ... | Saucer. | 3 | ...... | ,, |

Table (*continued*).

| Name of Tor. | Direction of Perpendicular Joints. | If Basin and Shape of Basin. | Diameters N. & S. | E. & W. |
|---|---|---|---|---|
| Kestor | ......... | ......... | 96 | 80 |
| " | ......... | ......... | 15 | 12 |
| " | ......... | ......... | 28 | 26 |
| Middletor | N.E. by N. to S.W. by S. | Oval. | 34 | 29 |
| Frenchbere Tor | N.W. to S.E. and N.N.E. to S.S.W. | " | 13 | 11 |
| Thornworthy Tor | ......... | None. | ... | ... |
| Puckie Stone | (Not *in situ.*) | Irregular. | 40 | 43 |
| Tor by Coombe | N. by W. to S. by E. | Oval. | 31 | 20 |
| Middleton Hill | N.W. by N. to S.E. by S. | Circular. | 24 | 24 |
| | S.W. by W. to N.E. by E. | Oval. | 22 | 24 |
| " | N.W. to S.E. | " | 48 | 40 |
| Teignvor | (Not *in situ.*) | " | 35 | 52 |
| Great Rocks | (Query if *in situ.*) | " | 15 | 17 |
| " | ......... | " | 24 | 21 |
| " | ......... | " | 18 | 22 |
| Logan Stone | (Not *in situ.*) | None. | ... | ... |
| Willistone | ......... | Irregular. | 23 | 12 |
| " | ......... | " | 32 | 16 |
| " | ......... | Triangular. | 14 | 16 |
| Hell Tor | E. by N. to W. by S. | Irregular. | 46 | 41 |
| " | N.E. to S.W. | Oval. | 54 | 42 |
| " | ......... | Quadrangular. | 40 | 42 |
| " | ......... | Irregular oval. | 144 | 132 |
| " | ......... | Irregular. | 38 | 44 |
| " | ......... | Oval. | 28 | 21 |
| " | ......... | " | 42 | 39 |
| Blackingstone | N.N.W. to S.S.E. | Circular. | 24 | 24 |
| *East of* | | | | |
| Ingstone | N.W. by W. to S.E. by E. | Oval. | 36 | 48 |
| Bullaton | (Not *in situ.*) | " | 52 | 34 |
| *Within the Watershed of the* | | | | |
| Punchbowl at Rushford | (Not *in situ.*) | Oval. | 14 | 18 |
| Sandsgate | N.N.W. to S.S.E. | Irregular. | ... | ... |

At Scorhill Tor, Wattern Tor, Wild

Between the Rivers Taw and West Okement, at Steeperton Tor, Hock
Yes Tor, and Dinger

| of Basins in inches. | | Average Height of Sides. | Shape of Bottom. | Central Depth of Saucer. | Contents. | Observer. |
|---|---|---|---|---|---|---|
| Greatest Direction. | Amount. | | | | | |
| N. and S. | 96 | 31 | Flat. | ... | Sphagnum, Peat, &c. | Ormerod. |
| S.W. & N.E. | 19 | ... | Saucer. | 2 | ...... | " |
| N.W. & S.E. | 28 | 4 | Flat. | ...... | ...... | " |
| " | 43 | 6 | " | ...... | ...... | " |
| N. and S. | 13 | 2 | " | ...... | ...... | " |
| ... | ... | ... | ... | ...... | ...... | " |
| N.W. & S.E. | 58 | 3 | " | ...... | As Mistor. | " |
| N. and S. | 31 | 3 | " | ...... | ...... | " |
| ... | ... | ... | Saucer. | 7 | ...... | " |
| N.W. & S.E. | 26 | ... | " | 4 | ...... | " |
| N. and S. | 48 | 7 | Flat. | ...... | ...... | " |
| E. and W. | 52 | 3 | " | ...... | ...... | " |
| " | 17 | ... | Saucer. | 2 | ...... | " |
| N. and S. | 24 | 3 | Flat. | ...... | ...... | " |
| W.S.W. and E.N.E. | 27 | 3 | " | ...... | ...... | " |
| ... | ... | ... | ... | ...... | ...... | " |
| ... | ... | ... | Flat. | ...... | ...... | " |
| N. and S. | 23 | 3 | " | ...... | ...... | " |
| ... | ... | ... | " | ...... | ...... | " |
| N. and S. | 46 | 5 | " | ...... | ...... | " |
| " | 54 | 5 | " | ...... | ...... | " |
| N.W. & S.E. | 42 | 5 | " | ...... | ...... | " |
| ... | ... | ... | Caldron shape. | 60 | ...... | " |
| ... | ... | 6 | Flat. | ...... | ...... | " |
| N. and S. | 28 | 5 | " | ...... | ...... | " |
| S.W. & N.E. | 48 | 5 | " | ...... | ...... | " |
| ... | ... | 6 | ... | ...... | ...... | Addams. |

*Wray Brook.*

| | | | | | | |
|---|---|---|---|---|---|---|
| N.W. by W. and S.E. by E. | 52 | 19 | Inclined. | ...... | ...... | Ormerod. |
| N. and S. | 52 | 6 | Flat. | ...... | ...... | " |

*North Bank of the River Teign.*

| | | | | | | |
|---|---|---|---|---|---|---|
| E. and W. | 18 | ... | Cup. | 6 | ...... | Ormerod. |
| N.N.W. and S.S.E. | 40 | 2 | Flat. | ...... | As Mistor. | " |

Tor, and Hound Tor—no basins.

Tor, Belstone Tor, Higher Tor, Scarey Tor, Row Tor, West Mill Tor, Tor—no basins.

## April 14, 1858.

The following communications were read:—

### 1. *On the occurrence of* Graphularia Wetherellii *in* Nodules *from the* London Clay *and the* Crag. By N. T. Wetherell, Esq., M.R.C.S., &c. (Communicated by the President.)

[Abridged.]

About twenty-six years since, on looking over some London Clay from a well at Colney Hatch Lane, near Muswell Hill, I discovered some curious fossils which at the time puzzled me very much. Having obtained, some years after, better specimens of these fossils from a well at Lower Heath, Hampstead, I submitted them to the inspection of Mr. James De Carl Sowerby; and he expressed an opinion that they were fragments of the horny axis of an extinct species of *Pennatula*, and gave me for comparison some examples of the recent *Pennatula phosphorea* of the British coast. In 1834 I drew up a paper for the Society, on some fossils from the south side of Hampstead Heath; and in one of the plates appended to the paper, some fragments of the *Pennatula* were figured*. In 1850 the first part of the beautiful monograph of British Fossil Corals by Milne-Edwards and Jules Haime was published by the Palæontographical Society. In this part the authors, after giving a full description of the fossil, state their reasons for separating it from *Pennatula* and forming a new genus, which they named *Graphularia*; the *Graphularia Wetherellii*, found in the London Clay at many places†, and also in the Barton clay, is the only known type of the genus‡.

I have for a long time considered that a great many of the calcareous nodules found in the Crag have been washed out of the London Clay at some former period, and that the greater number were not "coprolitic," as some geologists imagine§. Nodules of this description abound in some of the localities of the London clay, especially at Highgate and its vicinity; and I think the state in which they occur in the Crag || is owing principally to their having been rolled, and to a chemical development of the iron. I have just made an interesting discovery which tends to support my views.

From the London Clay at Hampstead I have lately obtained a cylindrical nodule which has clearly been formed around the horny

* "Observations on a well dug on the south side of Hampstead Heath." Geol. Trans. 2nd Series, vol. v. part 1. p. 136. tab. 8. fig. 2 *a*, *b*.

† Highgate; Finchley; Fortis Green, near Finchley; Colney Hatch Lane; Muswell Hill; Hornsey; Holloway, near Copenhagen House; Hampstead Tunnel; Haverstock Hill, near Chalk Farm; Sheppey; and Herne Bay.

‡ Milne-Edwards and J. Haime, Monog. Brit. Foss. Corals, p. 41. pl. 7. fig. 4.

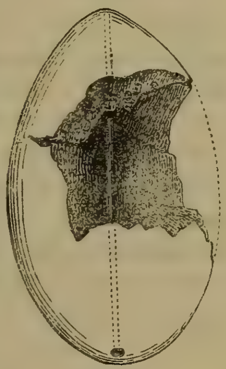
§ I have a fusiform coprolite from the London Clay near Chalk Farm, an inch and a quarter long, five-fourths of an inch broad, and evidently spiral in structure. As this is the case, some of the nodules in the Crag may be decidedly coprolitic, and derived from the London Clay; but I do not consider that, because a nodule contains phosphate of lime, it must of necessity be a coprolite.

|| My thanks are due to Mr. Rupert Jones for some kind suggestions relating to this part of the paper.

axis of a *Graphularia Wetherellii.* Very fortunately, not only the quadrangular form of the fossil is preserved, but also the radiated structure, as seen in the section.

Now this discovery in itself is not important, but it becomes interesting when the same thing is proved to occur in nodules found in the Crag. On the table are some oviform nodules from the Crag, which exhibit the same kind of nucleus. In many instances the subcylindrical form of the nodule somewhat corresponds with that of the contained fossil; but the oviform nodules just mentioned show that this is not always the case.

*A broken Nodule from the Crag, having for its axis a portion of the stem of a* Graphularia.



Examining many of the nodules, we shall find that, in the first place, as a general rule, there is the *Graphularia*, or a fragment of it, in the centre. Sometimes, however, the coral is entirely wanting, there being only a quadrangular, a subangular, or a cylindrical tube, corresponding to the different portions of the stem that has been removed. Next there is a generally subcylindrical or fusiform coating of clay over the fossil, varying in diameter in different specimens from half-an-inch to an inch. Upon this first coating is placed a series of indurated layers of clay, often blackened by iron, varying in number to ten or more; and lastly there is another argillaceous coating, finishing off the nodule into an oval and sometimes a pyriform shape, with a rough external surface.

Now this first coating of clay is generally of a fusiform shape and in juxtaposition to the nucleus. It is not usually so compact as the layers which enclose it; and sometimes it is so soft and powdery, that it may easily be scraped away with a penknife. It is more or less ferruginous; and instances are not wanting where it has almost entirely crumbled away, leaving a hollow tube, almost large enough to admit of the introduction of the little finger.

The layers vary in thickness in different specimens; sometimes they are not thicker than tissue-paper, and at others about half an inch in thickness. Again, these layers are often striated longitudinally—the striæ being very numerous and thick-set, and occasionally having waved lines passing transversely over them; and well-preserved nodules exhibit their striæ on all the layers. Some instances occur where the *layers are bent inwards.* The longitudinal striæ are in a few instances broader, more prominent, and less numerous. The material of the nodules investing the coral appears to be entirely argillaceous, with different modifications, and with a variable admixture of iron*.

I will now briefly call attention to some other nodules of a different character. In them the centre is composed of a subcylindrical mass of minute bodies of a very peculiar character.

* The first and second coatings of clay effervesce with acid in a greater degree than the other layers.

They vary in appearance in different specimens. In some nodules the mass is made up of small cylindrical bodies, irregularly grouped together; whilst in others, equally numerous, the mass consists of small oviform bodies. Their origin is at present involved in obscurity. I think the oviform bodies may probably turn out to be eggs of some small invertebrate animals*; and some of the others may be due to *Clionites* or burrowing Sponges, the burrows having been filled up with clay hardened and blackened by iron. This, however, requires further investigation. These curious masses are closely invested by argillaceous laminæ, similar in form to those of the nodules previously described, but apparently less numerous. A few nodules have the laminæ marked transversely with numerous waved striæ; and I have one specimen with a few oblique striæ, and another with very prominent and rough transverse striæ.

Obscure as the origin of the peculiar formation of the nodules certainly is, I cannot but remark that possibly, after the first calcareo-argillaceous coating was aggregated around the nucleus of the future nodule, whether the stem of a *Graphularia*, or a long row of massed oviform bodies, the further coatings of clay, their frequently separate condition, and their peculiarly striated surface appear to be due, to some extent, to a kind of intermittent pressure of the matrix, either from its own weight, or from a kind of "creep" affecting the mass whilst the longitudinal axes of the nuclei were in a more or less vertical position.

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## 2. *On the* Extraneous Fossils *of the* Red Crag. By S. V. Wood, Esq., F.G.S.

The Deposit called the Red Crag indicates the action of strong reversible or tidal currents, and is more disturbed and littoral in its character than any portion of a formation at present known; and, for its limited area, it contains a larger percentage of foreign† organic remains than any of which we have as yet a record. I know of no locality that appears to me more to resemble what was probably the local condition of the Sea of the Red Crag during the accumulation of the material herein enumerated than the conditions under which the Bay of Christchurch at present exists; and I believe that in the conflicting streams that now wash the shores of that neighbourhood may be found a cause sufficient to produce all the effects visible in the Red Crag,—only reversing the direction of the land, the sea of that period opening to the northward.

* Figures of groups of similar little oviform bodies, from the Author's Collection, were published in the Magazine of Nat. Hist., 1839, plates 8 and 9. See also Quart. Journ. Geol. Soc. vol. viii. p. 247, where Mr. Prestwich notices similar minute oviform bodies in the Thanet Sand. When masses of these corpuscles occupy the cylindrical cavities in the fossil bored wood of the London Clay, they singularly resemble the excrementitious matter left by the Cossus and other large caterpillars in the galleries excavated by them.

† See the Presidential Address, Quart. Journ. Geol. Soc. No. 56, p. cxxxiii., for some pertinent remarks on extraneous or foreign fossils.

To ascertain the age of the Red Crag by the "percentage test," could only be effected by the exclusion of a large portion of its contents; and, when we have got rid of those fossils which we know to belong to some remote anterior period, we should then have to contend against the doubtful admission of many species that may have been introduced from the deposits immediately antecedent. A large number of the shells have in all probability, as suggested by Sir Charles Lyell, been washed into the Red Crag Sea by an underwater abrasion of the older beds; and the shells by such action may have suffered little or no deterioration during the removal, and when redeposited would have nothing in their appearance to indicate their derivative nature, nor would their specific character help us to decide whether they were natives or foreigners; and that is probably the condition of many of the specimens found in this fossil museum of natural curiosities.

The following genera may have supplied species to the Red Crag, namely, *Chama*, *Cardita*, *Astarte*, *Cyprina*, *Isocardia*, *Limopsis*, *Turritella*, *Vermetus*, *Cancellaria*, *Pleurotoma*, *Terebra*, *Voluta*, and *Pyrula*. All of these have been obtained from the disturbed portion of the Red Crag; and none of them are found in the genuine deposit at Walton-on-the-Naze, which I consider the type of the Red Crag. Out of 240 species of mollusca found in the Red Crag, and belonging truly to a Modern Tertiary period, fifty may perhaps be considered as derivative fossils.

The following species found in the Red Crag may be enumerated as having been possibly derived from the Coralline Crag.

Voluta Lamberti.
Cypræa affinis.
Erato Maugeriæ.
Terebra inversa.
Cassidaria bicatenata.
Nassa conglobata*.
—— labiosa.
—— prismatica.
Trophon alveolatum.
—— consociale.
Pleurotoma carinata.
—— intorta*.
—— semicolon?
Cancellaria mitræformis.
—— scalaroides.
Scalaria foliacea,
—— varicosa.
Vermetus intortus.
Dentalium costatum.

Ostrea princeps.
Hinnites Cortesyi.
Pecten dubius.
—— maximus?.
Pinna pectinata.
Limopsis aurita.
Mytilus hesperianus.
Chama gryphoides.
Diplodonta dilatata.
Lucinopsis Lajonkaireana.
Cardita senilis.
—— chamæformis.
—— orbicularis.
—— scalaris.
Astarte Basterotii.
—— Burtini.
—— gracilis.
—— incrassata.
—— mutabilis.
—— Omalii.
Isocardia cor.
Cyprina rustica.
Venus casina?.
—— ovata?.
Circe minima.
Tapes texturata*.
—— virginea?
Mactra glauca*.
—— obtruncata.
Panopæa Faujasii.
Mya truncata?.
Glycimeris angusta.

* These have not yet been found in the Coralline Crag, but they probably belonged to the period of that deposit.

Gastrochæna dubia.
Teredo Norvegica.

Terebratula grandis.

Balanus concavus.
—— crenatus.

Sphenotrochus intermedius.
Cryptangia Woodii.
Balanophyllia calyculus.
Fascicularia.
Theonoa.
Cellepora.
Eschara monilifera.
Alcyonidium circumvestiens.

In the Table appended to these remarks (see p. 43), no notice whatever is taken of these doubtful fossils, as it is possible that they, or at least some of them, may have lived on to the Red Crag Period from that of the Lower or Coralline Crag; still, however, there are some few extraneous fossils of the alien character of which there is no doubt; but, the species not having yet been obtained in any other deposit, we are unable to refer them decidedly to a particular period. There is, however, an unmistakeable character about them by which we may, I think, with every probability not only infer their derivative nature, but assign to them the formation to which they originally belonged. I would especially mention the casts of two species of *Pulmonifera*: one a large elevated *Helix*, and the other a species of dextral *Bulimus*, differing from anything that has hitherto been described as from the Older Tertiaries of this or any other country known to me; but I have very little doubt they are casts of shells from a freshwater deposit, probably belonging to, or synchronous with, one of the Older divisions of the Eocene Formation.

The air-breathing animals of all kinds found in this marine deposit, I have considered as not entitled to be enumerated with the real inhabitants of the Red Crag Sea, although it is probable that *Helix rysa* and *Planorbis marginata* may truly belong to the age of the bed in which they are found. The terrestrial Vertebrates are certainly intruders into the Crag, to whatever period they may be assigned; and the opinions of the present day respecting the Age to which they belonged are in a most unsatisfactory state, our ablest Palæontologists being at variance in the assignment of the species. Prof. Owen* considers many of them as having been derived from the Miocene or Middle Tertiaries, while Dr. Falconer† has more recently identified them with species belonging to the Newer Tertiary or Pliocene Period; and, in this state of uncertainty, I have purposely omitted their specific names from my Catalogue, which is entirely restricted to the Red Crag.

Mr. Charlesworth, it is well known, orginally separated the Crag deposits into three chronological groups, but the propriety of these divisions has lately been called in question, and it is asserted they all belong to one period as indicated by the Mammalian Remains that have been found in them.

Whatever may be considered necessary to mark what is called a Geological Period, whether it be an entire alteration of the fauna of a preceding specified portion of the world's existence, or the change

* Quart. Journ. Geol. Soc. vol. xii. p. 217, &c.
† Quart. Journ. Geol. Soc. vol. xiii. p. 350, &c.

only of a particular kind, or merely an alteration of the conditions under which the deposits have been formed, is not of much importance, as the broadest divisions in geological sequence are in all probability only conventional, although necessary and most useful for the purposes of study. I can only say that, whether the Lower Crag be or be not entitled to be called Pliocene,—the Middle Crag, Newer Pliocene,—and the Mammaliferous or Upper Crag, Pleistocene,—they indicate great and successive changes; the Coralline Crag having been deposited in quiescent water with a facies of fauna different from that of the Red Crag; while previously to the deposit of the *native* bed at Chillesford, the land must again have undergone a subsidence. These differences denote changes of condition *in those localities, at least,* during their depositions; and, as such, I have considered the Red Crag to be a deposit of a distinct period.

In regard to the Cetotolites of the Red Crag, when first determined by Prof. Owen, they were considered by that gentleman as having been undoubtedly derived from the London Clay, and at p. 542 of the 'History of British Fossil Mammalia' are the following words:—"that the fossil ear-bones and Cetacean teeth of the Red Crag have been washed out of the subjacent Eocene Beds, is probable from the fact of a Cetotolite having been discovered in the London Clay itself; and from fragments of other Cetaceous bones having been obtained from the same formation. In the Hunterian collection of fossils, I have determined some considerable fragments of bone to be Cetaceous: they were recorded to be from Harwich Cliff, Essex, and were in the same completely-petrified condition as the fossil ear-bones from the Red Crag." There is no doubt of the *fact* of these Cetacean bones having been obtained from the Harwich Cliff, but the inference that they were derived from the London Clay does not appear to be a necessary one. The formations in this locality are the same as those occurring on the eastern side of Suffolk, the basement portion of the Coast as far as Woodbridge is the London Clay, capped by the Red Crag and sands of more modern date; and, although the Crag is no longer seen at Harwich, in consequence of the encroachments of the sea, it is the spot whence Dale in 1730 obtained all his Crag fossils, and therefore the Whales' bones there found are no better evidence of Eocene derivation than those obtained at Felixstow or at Sutton.

The Whales' bones that have lately been obtained in great abundance are all or nearly all found at the basement portion of the Crag deposit, in association with the phosphatic nodules and fish-teeth that have been presumptively considered as derivative fossils of the London Clay; and, whether these Cetotolites or Cetacean remains were really derived from the Older Tertiaries, or from some more modern period, their accumulation in such large numbers in so comparatively confined a spot indicates strongly their derivative nature, and that they do not strictly belong to the deposit in which they are now found. We must therefore seek for evidence as to whether the Older, the Middle, or the Newer Tertiaries be the formation whence they were derived.

Capt. Alexander many years since procured a Cetotolite from the Coralline Crag, a notice of which was given in the Proceedings of the Society*. This ear-bone was found on that part of the Coralline Crag which is composed entirely of the calcareous remains of the *Bryozoa,* where scarcely a single shell is to be met with, and which may be considered as having been formed in somewhat shallow water. Now, since the Coralline Crag is destitute of extraneous material (or at least nearly so), it would, I consider, be a conclusion unsupported by evidence to assign to a bone of this nature a derivative, rather than a proper character, with reference to the deposit in which it occurs. There seems to me to be no reason for supposing but that the animal to which this ear-bone belonged was an inhabitant of the seas of the Coralline Crag Period, and had been stranded in the manner in which *Cetacea* are often found on our own shores at the present day. I may, however, add, that I have found a few small vertebræ, as also a few fragments of larger bones, in the Coralline Crag belonging probably to the *Cetacea*; but I have never seen from that formation a vertebra which could be said to have belonged to any animal possessing such otolites as the one found by Capt. Alexander in the Coralline Crag, or as are now yielded in such numbers by the Red Crag. Mr. John Brown, F.G.S., has obtained a small Cetotolite from the Coralline Crag, at Sudbourne, precisely resembling specimens which have been found rather numerously in the Red Crag at Sutton; so that the evidence is strong that some of these Cetacean remains of the Red Crag have been derived from the formation immediately antecedent, namely, the Coralline Crag†. Mr. Acton has recently obtained three or four Cetacean teeth, around which is an agglomeration similar to that which is commonly seen adhering to the teeth of *Lamna, Otodus,* &c., fossils belonging to the Older Tertiaries: but the material surrounding the Cetacean teeth differs in composition from that which surrounds the base of the fish-teeth of the London Clay. The two therefore, from this evidence, do not appear to be derived from the same source.

In my Monograph of the Crag Mollusca (Palæontograph. Society) these Whales' bones were inadvertently placed with the Older Tertiary fossils. The mineral, or rather the metallic, character of these remains probably owes its origin to the Red Crag itself, as it pervades the specimens undoubtedly derived from the Older Ter-

* Geol. Proc. vol. iii. p. 10, 1838.

† A few hours previous to the reading of this paper, a very interesting drawing of a vertebra was obligingly sent to me from Malta by Sir Wm. Reid, F.G.S. (lately deceased). This is a representation of a bone evidently belonging to one of the Marine Mammalia; and I have also since received, from the same source, a fossil which appears to be the fragment of a rib of an animal of that class. I am also informed that Cetotolites have been found at Malta in association with the teeth of *Carcharodon megalodon.*

I feel rather at a loss to venture an opinion as to whence these Cetacean bones now found so abundantly in the Red Crag were derived. The Coralline Crag may have contributed a large portion, while it is still possible some may have been contemporaneous with the *C. megalodon.*

tiaries as well as those from the more modern formations, such as teeth of *Equus*, horns of *Cervus**, &c.

In a Paper on the Fish-remains of the Red Crag, which I had the honour to read before the Society, March 9, 1853, it was incidentally mentioned that the land *Mammalia* of the Red Crag were supposed to have been derived from some destroyed freshwater bed, probably of the age of the Coralline Crag; and, as the *Mollusca* of this formation indicated a close Zoological relationship with the fauna of the present seas, the Mammalian Remains were, on that account, considered as belonging to the upper portion of the Tertiary Series. It is certainly possible that they might have been entombed in the position in which they are now found; but it is difficult to conceive that such was the case. Where would there be now found remains of terrestrial *Mammalia* occurring in the like abundance, associated with a littoral *Mollusca*? Mammalian remains are only found in abundance in deposits formed by deltas of rivers, or by lakes, or in morasses. They may occur in true marine deposits, as in the case of the *Hyracotherium* in Herne Bay; but, in such case, the fossil is a rarity. Take, for instance, the deposits now forming on any of our own shores; in none of these would there be entombed in association with the littoral *Mollusca* any abundance of the remains of terrestrial *Mammalia* now inhabiting those shores; whereas the constant erosion of a cliff formed by a deposit rich in vertebral remains, as for instance the Cliff at Hordle, would supply an abundance of these remains; the more indurated portions of which would be swept into the banks now forming under the contiguous sea.

The identifications of the fossil fish-teeth with those of the London Clay species are inserted in the Table without entire confidence, although the forms give fair presumption for the assignment. My object is merely to insert as species those fossil teeth found in the Red Crag which fairly correspond with those obtained from an older formation. The determination of a species upon a small portion of an animal, such for instance as the single tooth of a fish, where the jaw contains a large number, and those sometimes of a varied form, is perhaps scarcely a sufficient dependence for specific distinction; and the magnitude of one of these fishes has been assumed from a character of the like kind. The proportions of *Carcharodon megalodon* have been said (from the time of Shaw to the present day) to rival those of our largest *Cetacea*, and this length is calculated from the dimensions of the tooth†. We have not at present the means of knowing what might have been the proportions of the joints constituting the vertebral column of these extinct species. Should we be fortunate enough to obtain an element of this kind to

* Mr. Acton has also obtained from the Red Crag of Sutton a tooth of the *Mastodon*, in which the depressions between the papillæ of the grinding surface are filled with the same material as that which adheres to the Cetacean teeth alluded to. This would appear to favour the belief that the tooth of the *Mastodon* and the teeth of the *Cetacea* obtained this agglomeration while they were in the Red Crag.

† British Assoc. Report, 1851, Sect. p. 54.

assist our calculations, the length of these extinct animals to which the large teeth belonged may probably be found not to have exceeded in length that of sharks existing in the seas of the present day, namely 60 feet.

Besides the fish-teeth, which are found in great abundance in the Red Crag, there are "coprolitic" casts of the animals themselves, indicating their derivation to be from a bed of the Older Tertiary Period. These specimens are generally in a fragmentary, often in a rolled and mutilated, condition. They bear a strong resemblance to, and indeed in a few instances the Crag specimens can be identified with, the fossil fishes of the Isle of Sheppey.

A few specimens only of *Cephalopoda* have come under my notice. These consist of, first, *Belemnites*, probably belonging to two species, and derived from the upper part of the chalk formation. They are silicified, having the surface ornamented with a peculiar arrangement of elevated concentric ridges, or points, somewhat irregular and undulating. I have separated these into two species, although the specimens are not in the most satisfactory condition for such a purpose; but one or two show a great eccentricity in the alveolus; and I have depended upon that character alone for the distinctions. Secondly, nodules containing impressions of *Ammonites*. These appear to consist of calcareous clay, probably of the age of the Lias. Thirdly, a few nearly perfect casts of *Nautilus* have been obtained; and segments, or casts of the compartments, are occasionally met with. Those which I have seen were not in a condition to justify the assigning to them more than a generic character. As, however, they are casts formed of the material which resembles the phosphatic clay of the Older Tertiaries, they are on that account presumed to have been derived from the London Clay. The evidence afforded by the derivative *Mollusca*, or rather I should say the *Gasteropoda* and Bivalves, point in the same direction as the greater part of the Fish-remains, namely, to the London Clay; but the *shells* of the Older Tertiaries are rarely found, as might be expected; and the casts, which are seldom in good condition, will only occasionally afford a specific character, although their general form will admit of no mistake. Those which give a fair determination indicate their age to be that of the *older* portion of the Eocene deposits, with, however, the exception of one shell, *Ostrea flabellula*, which belongs to the upper division; but even this is found in the Bracklesham beds, and I have seen in Mr. F. Edwards's Collection a shell much resembling it, which came from Clarendon.

Many Crustacean remains (five, perhaps six, species) found in the Red Crag can be traced to the Eocene deposits. Some of these are imbedded in the phosphatic clay, and others are simply casts formed of that material. They are not only identical with London Clay species, but there is oftentimes so strong a resemblance between the Crag specimens and those from Sheppey, that, with the exception that the former are tinged with the ochreous colour of the Red Crag and are more rubbed, they could scarcely be distinguished the one from the other. I believe all these derivative Crag specimens are procured only from the lower stratum, or that in which the phosphatic nodules are obtained.

Specimens of wood, of a tropical character, are frequently met with in association with these animal remains: I have found such pieces of wood perforated with existing *Pholades* (*Ph. parva* and *Ph. crispata*), the wood itself being in a lapideous or metalliferous condition; but this metallic impregnation may perhaps have been derived from the mineral matter of the Red Crag, subsequent to the removal of the fossil from the London Clay; the tube of *Teredo antenautæ* is found in the same bed, but I have not met with this species in the Red Crag, in what may be called its natural habitation.

A number of indeterminable, or at least undetermined, fossils have been obtained from the Red Crag, which, as to their derivation, may be referred to the London Clay. I would especially particularize some spirally-formed bodies which have been regarded as the coprolitic rejectamenta of the Shark tribe, as these animals have a spiral intestine. The Crag fossils in question appear to me to be rolled and water-worn specimens similar to some Serpulaform bodies which have been found in the London Clay of Highgate, figured and described in the Mag. Nat. Hist. 1839, pl. 8. fig. 15, by Mr. N. T. Wetherell. Whatever may be the nature of these spiral fossils, and whenever their characters shall have been determined by the more perfect specimens of the London Clay, there is, I think, little doubt but that the Crag specimens of the so-called spiral "coprolites" have the same origin, and were derived from the same formation. The *projecting spiral* in the Crag fossil is different from the clay contained within its fold, and not homogeneous, as it would have been, if it were of coprolitic origin. Another Crag fossil is, I think, worthy of some remark. It resembles pl. 1. figs. 1 & 1*a* of the Mag. Nat. Hist. for 1839 before referred to; indeed there is no doubt of the identity with the London Clay specimens. They are inserted among the fossils *Incertæ sedis* in 'Morris's Catalogue of Brit. Fossils,' under the name of *Nidulites* (Salter). These small bodies have been considered by Mr. Prestwich (Geol. Journ. vol. viii. p. 247, pl. 16. fig. 11) as the eggs of *Mollusca*, and by others as the spawn of *Crustacea*; they have also been referred to a coprolitic origin; but that they are the ova of some animal seems the better opinion*. They appear too regular in their arrangement to be the seeds of any vegetable.

My list contains the names of 109 species of true derivative fossils; and of this number there are 57 which can be traced to the London Clay, or at least to the Older Tertiaries, with a few others probably from the same formation, but not in a sufficiently perfect condition for determination: 30 have belonged to a much more recent date; 9 were Chalk fossils; 4 appear to have been derived from the Lias or Lower Oolite; and, if the identifications be cor-

* See also Mr. Wetherell's paper "On Certain Nodules of the London Clay in the Crag," *supra*, p. 32.

rect, 6 belong to, or were derived from, the Middle Tertiaries; for the *Cetacea* and *Ziphius* I have assigned only a doubtful origin.

It will appear from the above analysis that the London Clay has made the largest contribution of species. The greater portion of these organic remains consist of the teeth of Sharks; and the individual specimens from the Older Eocene formation bear a larger proportion to the specimens from any other deposit (even allowing for the greater number of teeth these animals possessed) than do the individual species from that deposit to the individual species from any other; and I believe the Red Crag Sea to have been principally bounded by land belonging to the London Clay; and that these fossils have been introduced into the Red Crag Sea by the simple operation of coast-action; their rolled or bouldered condition resulting from strong or opposing currents running into, or through, that sea.

Professor Henslow, as it is well known, in 1843 first brought into notice a material he had discovered in the Red Crag, which was then considered likely, and has since proved, to be a valuable boon to the agriculturist; and, as this substance contained a large portion of the phosphate of lime, it was in consequence imagined to be of *coprolitic* origin, and the name of "coprolite" has to this day been retained by the diggers and dealers in that article.

The opinions respecting the nature of this material, and of the source whence it was derived, were for some time in an unsettled state, and Mr. John Brown submitted to an eminent chemist, Mr. Richard Phillips, for analysis, some specimens of indurated clay from the Red Crag as well as from the London Clay. The result of that gentleman's examination was published by Mr. Brown in 'Charlesworth's London Geological Journal' in 1846, showing a very strong resemblance in the component parts of the clay from the two different formations; and, although the opinion respecting the *coprolitic* origin of the clay has been generally discarded, it is most probably of animal derivation. There is every reason to believe that this phosphatic clay is foreign to the bed in which it is found, and that it has been derived from some antecedent formation; and, as the Fishes and Crustacea from the London Clay are found imbedded in this material, or their animal portions replaced by it, there is no doubt that some of the clay has been derived from the Older Tertiaries. As, however, this same "coprolite" is met with in the Coralline Crag, this latter formation has also contributed, I believe, a very large portion*.

* Since this Paper was read, I have again visited the Crag district, and have obtained from the Coralline Crag, at Ramsholt and Sutton, not only amorphous specimens of this "coprolite," which constitutes the main portion of the commercial article, but I have found specimens of a peculiar form and character, precisely resembling those which are found in the Red Crag. I would more especially mention some elongate and pointedly oviform nodules of this clay, possessing a smooth exterior with a regular polygonal fracture. These nodules (larger than pigeons' eggs) were found in the Coralline Crag where the shells indicate a quiescent deposit, or, at least, where there could have been only a

The basin in which were accumulated these presumed derivative fossils is rather more limited than the Red Crag itself, the outskirts of the existing portion of that deposit not appearing to yield any of the so-called "coprolitic" material, and not having been disturbed by the agriculturist for that purpose. The longest diameter of the true "coprolitic" basin extends about ten or twelve miles; and in this limited area there are spots in which these foreign ingredients have been more especially deposited. Thomas Waller, Esq., of Sutton, who has excavated a large amount of the phosphatic clay, and is well acquainted with the inorganic contents of the Red Crag in his immediate neighbourhood, tells me that the proportion of these clay-nodules to the chalk-flints is about 8 to 1. This is where the "coprolite" is in the greatest abundance; and it is there also that flints are in excess of other localities, so far as I have been able to observe them, though flints are occasionally found in the outskirts of this basin where the "coprolite" is not seen. I am scarcely able to say that the flints are more worn or rolled than the clay-nodules; they are somewhat angular, with the angles rounded off; and they appear to me to have been simply washed from the Chalk and transported into the Crag-basin, and not from any great distance; specimens of large size (from 8 to 10 inches in diameter) are but little bouldered. The organic remains of the Chalk do not bear that proportion to those of the London Clay which the inorganic are supposed to do; the species are few in number, and the individuals are very rare: this arises no doubt from the paucity of fossils in the destroyed portion of that formation. The specimens from the Older Secondary rocks are even still more rare.

Mixed with this "coprolite" are a number of sandstone-nodules* which (with the flints) are thrown aside by the "diggers" as useless for their purpose. These nodules are chiefly siliceous; but they exhibit a slight effervescence on being touched with muriatic acid, at least this is the case with those specimens formed around a calcareous nucleus. Many of them contain the cast of a mollusc, as if the sand had aggregated around the shell, the calcareous matter forming the cementing material of the nodule; but the greater number of the nodules are free from any such nucleus. These sandstones, Mr. Waller tells me, bear about the same proportion to the flints that the flints do to the "coprolite," namely, 1 to 8;

slight movement of the water, for the large and fragile shells are found in association with these smooth and polished "coprolitic" specimens. Their smooth and rounded condition, therefore, does not appear to have been the result of water-action while in the Coralline Crag.

Phosphatic clay has been procured from the Greensand, and, I believe, from other formations; but the nodules in the Red Crag are no doubt derived conjointly from the London Clay and the Coralline Crag—S. V. W. Sept. 1858.

* In a List of Fossils from the Red Crag at Beaumont, printed in April 1846 by Mr. John Brown, F.G.S., are included the following inorganic materials:—"Agates; Chert; Septaria; Quartz (the milky variety, in large boulders); Quartz, highly crystalline, similar to that at Lickey-hill near Bromsgrove; Micaceous schist, in pebbles; and Flints from the Chalk, very large and angular, others rounded into boulders and pebbles."

and, judging from the species contained within them, so far as I have seen, they appear of modern origin, probably of the age of the Older Crag. There is, however, no part of the Coralline Crag, now existing, so thoroughly siliceous as is the matrix of these fossils; it more resembles, in lithological character, the sandstones at Lenham in Kent, without the colouring matter of those masses.

There are only two species of *Mollusca* from Lenham* that bear any sort of similitude to, or could be compared with, those in the sandstone-casts of the Red Crag; the one a *Pyrula* and the other a *Pectunculus*. Of the former, I have seen only a fragment, and it could only be assigned generically; and the latter belongs to a genus in which there is great difficulty in determining a species, even where numerous and perfect specimens can be obtained for that purpose; this difficulty is, of course, much increased where casts only, and those neither numerous nor perfect, are all we have to depend on.

In endeavouring to trace the sources whence these extraneous materials have been respectively derived, there is not much difficulty in indicating the greater part of the formations that have so contributed. We find the London Clay in close proximity with deposits of the Older Pliocene Period; the Chalk shows itself at no great distance, both in Norfolk and Suffolk; and the few Older Secondary fossils may also have been brought from a not much greater distance than the Western Coast of Norfolk. It is rather with respect to the Middle Period of the Tertiaries that we are in some perplexity, if the fossil Fish-teeth from Malta and Suffolk be truly identical. The same may be said with regard to some of the Mammalian remains, such as *Hippotherium* and *Hyænodon*; presuming that they are species of the Miocene Period. In this case we must have in the Red Crag the contents of destroyed portions, not only of marine but also of freshwater deposits of the Middle Tertiaries; and, as the specimens, of the marine animals at least, are by no means few in number, the deposits that supplied them could not have been very remote. The Limburg beds† appear to make an approach to what we require for some of these fossils, and may perhaps have contributed a portion.

* See Quart. Journ. Geol. Soc. vol. xiv. p. 334.
† Quart. Journ. Geol. Soc. vol. viii. p. 298, &c.

| Extraneous Organic Remains found in the Red Crag. | Derived from Secondary Formations. | Probably derived from Older Tertiaries. | Probably derived from Middle Tertiaries. | Probably derived from Upper Tertiaries. |
|---|---|---|---|---|
| Hyracotherium leporinum | . . | * | . . | . . |
| —— cuniculus | . . | * | . . | . . |
| Ursus | . . | . . | . . | * |
| Canis † | . . | . . | . . | * |
| Vulpes | . . | . . | . . | * |
| Felis | . . | . . | . . | * |
| —— | . . | . . | . . | * |
| Trogontherium | . . | . . | . . | * |
| Mastodon ‡ | . . | . . | . . | * |
| Rhinoceros | . . | . . | . . | * |
| Equus | . . | . . | . . | * |
| Hippotherium | . . | . . | * | . . |
| Coryphodon ? | . . | * | . . | . . |
| Tapirus | . . | . . | *? | . . |
| Sus | . . | . . | . . | * |
| —— | . . | . . | . . | * |
| Hyænodon | . . | . . | * | . . |
| Cervus | . . | . . | . . | * |
| —— | . . | . . | . . | * |
| Balænodon affinis | . . | . . | . . | *? |
| —— definita | . . | . . | . . | *? |
| —— emarginata | . . | . . | . . | *? |
| —— gibbosa | . . | . . | . . | *? |
| —— physaloides | . . | . . | . . | *? |
| Delphinus | . . | . . | . . | * |
| Physeter | . . | . . | . . | * |
| Crocodilus *vel* Alligator | . . | * | . . | . . |
| Chelone ? | . . | * | . . | . . |
| Trionyx ? | . . | * | . . | . . |
| Palæophis toliapicus ? | . . | * | . . | . . |
| Ziphius (2 species) | . . | . . | . . | *? |

† The fossil skull of *Meles taxus*, in the Museum of the Philosophical Institution at York, spoken of, at p. 111 of 'Hist. British Fossil Mammalia,' as having been obtained from the Red Crag at Newbourne, was dug up, I am informed, from one of the more recent fluviatile deposits.

‡ Remains of *Elephas* are quoted from the Mammaliferous Crag near Norwich, and numerous Elephants' teeth have been dredged up on the Essex Coast, from what are called the West Rocks. These latter teeth are generally tinged with a reddish colour, and are considered as fossils of the Red Crag; but there are freshwater deposits, of a posterior date, in that district; and these *may be* remains from one of those beds: they have not the appearance of true derivative fossils. I have never seen or heard of a specimen that has yet been procured from the "coprolitic" diggings, or from any genuine portion of the Red Crag; and, as there is no sufficient evidence (at least to the present time known to me) of its existence in that deposit, the name of the genus is not inserted in my List. I am aware that the able geologist, Mr. Prestwich, is of opinion that the Norwich beds are only the estuary portion of the Red Crag; but this is a point not quite established.

| Extraneous Organic Remains found in the Red Crag. | Derived from Secondary Formations. | Probably derived from Older Tertiaries. | Probably derived from Middle Tertiaries. | Probably derived from Upper Tertiaries. |
|---|---|---|---|---|
| Myliobates | .. | * | .. | .. |
| Ætobates | .. | * | .. | .. |
| Raia ornata? | .. | .. | .. | * |
| Pristis | .. | * | .. | .. |
| Zygæna? | .. | * | .. | .. |
| Lamna elegans | .. | * | .. | .. |
| —— gracilis? | .. | * | .. | .. |
| —— cuspidata | .. | * | .. | .. |
| —— contortidens | .. | * | *? | .. |
| —— verticalis? | .. | * | .. | .. |
| —— Hopei? | .. | * | .. | .. |
| Carcharodon megalodon | .. | .. | * | .. |
| —— sulcidens | .. | .. | * | .. |
| —— ——? | .. | * | .. | .. |
| Oxyrhina hastalis | .. | .. | * | .. |
| —— plicatilis | .. | .. | * | .. |
| —— Desorii? | .. | .. | * | .. |
| —— trigonodon? | .. | .. | * | .. |
| Otodus obliquus } | .. | * | .. | .. |
| —— lanceolatus } | .. | * | .. | .. |
| Galeocerdo aduncus | .. | .. | * | .. |
| Notidanus primigenius | .. | * | .. | .. |
| Edaphodon | .. | * | .. | .. |
| Pycnodus toliapicus | .. | * | .. | .. |
| Phyllodus polyodus | .. | * | .. | .. |
| Anarrichas | .. | .. | .. | * |
| Cœlorhynchus | .. | * | .. | .. |
| Tetrapterus? | .. | * | .. | .. |
| Halecopsis lævis | .. | * | .. | .. |
| Belemnitella mucronata | * | .. | .. | .. |
| —— lanceolata? | * | .. | .. | .. |
| Ammonites | * | .. | .. | .. |
| Nautilus | .. | * | .. | .. |
| Helix pulchella | .. | .. | .. | * |
| —— rufescens | .. | .. | .. | * |
| —— rysa | .. | .. | .. | * |
| —— ——? | .. | * | .. | .. |
| Bulimus | .. | * | .. | .. |
| Planorbis marginatus | .. | .. | .. | * |
| Cypræa | .. | * | .. | .. |
| Voluta Wetherellii | .. | * | .. | .. |
| Ancillaria | .. | * | .. | .. |
| Strombus | .. | * | .. | .. |
| Cassidaria striata? | .. | * | .. | .. |
| Conus Dujardinii | .. | .. | .. | * |
| Conorbis *vel* Pleurotoma | .. | * | .. | .. |
| Nassa conglobata | .. | .. | .. | * |
| Buccinum Dalei | .. | .. | .. | * |

| Extraneous Organic Remains found in the Red Crag. | Derived from Secondary Formations. | Probably derived from Older Tertiaries. | Probably derived from Middle Tertiaries. | Probably derived from Upper Tertiaries. |
|---|---|---|---|---|
| Pyrula acclinis | .. | .. | .. | * |
| Fusus ? | .. | * | .. | .. |
| Cerithium ? | .. | * | .. | .. |
| Cancellaria læviuscula ? | .. | * | .. | .. |
| Vermetus Bognoriensis | .. | * | .. | .. |
| Pleurotomaria Anglica ? | * | .. | .. | .. |
| Turritella imbricataria | .. | * | .. | .. |
| Natica —— ? | .. | * | .. | .. |
| —— —— ? | .. | * | .. | .. |
| Ditrupa incrassata ? | .. | * | .. | .. |
| Gryphæa dilatata | * | .. | .. | .. |
| Ostrea flabellula | .. | * | .. | .. |
| Pectunculus glycimeris | .. | .. | .. | * |
| Cardium | .. | * | .. | .. |
| Cyprina Morrisii | .. | * | .. | .. |
| Isocardia cor ? | .. | .. | .. | * |
| Astarte | .. | *? | .. | .. |
| Thracia *vel* Mya | .. | * | .. | .. |
| Teredo antenautæ | .. | * | .. | .. |
| Rhynchonella tetrahedra | * | .. | .. | .. |
| —— Martini | * | .. | .. | .. |
| Terebratulina striatula | .. | * | .. | .. |
| Xanthopsis Leachii | .. | * | .. | .. |
| —— unispinosa | .. | * | .. | .. |
| Xantholites Bowerbankii | .. | * | .. | .. |
| Hoploparia gammaroides ? | .. | * | .. | .. |
| Thenops scyllariformis | .. | * | .. | .. |
| Cidaris | * | .. | .. | .. |
| Ananchytes ovatus | * | .. | .. | .. |
| Astropecten crispatus ? | .. | * | .. | .. |
| Pentacrinus subbasaltiformis | .. | * | .. | .. |
| Paracyathus caryophyllus | .. | * | .. | .. |
| Ventriculites | * | .. | .. | .. |

### 3. *On a* Fossil Fruit *found in the upper part of the* Wealden Deposits *in* Swanage Bay, Isle of Purbeck.

By John Phillips, M.A., LL.D., F.R.S., Pres. G.S., &c.

But few of the numerous fossil remains of Plants in the Wealden and Purbeck deposits of the British Isles have as yet been completely described. Ferns, *Equisetaceæ*, Monocotyledonous plants, *Coniferæ*, *Cycadaceæ*, and *Characeæ* have been recognized by their leaves and stems. But fruits are uncommon. One of these is cycadaceous—*Zamiostrobus*, and there are two undetermined *Carpolithi**.

To this short catalogue I am now able to offer one addition, taken from a nodule of ironstone in the upper part of the Wealden beds, in Swanage Bay, at the close of 1857.

The general section of the strata near Swanage, on a line from north to south, shows, in succession, the Portland rock, the Purbeck deposits, the Wealden, and the Cretaceous beds. For the purpose of this notice, only Wealden groups require attention.

The upper part of the Wealden, as seen very completely in the Northern Cliffs of Swanage Bay, exposes about 700 feet of clays frequently red or purple, less frequently blue, greenish, or very pale, alternating with sandstones of different tints, mostly soft and fine-grained, but sometimes hardened by irony impregnation, or modified by admixture of pebbles. One band contains much lignite.

In the upper part of this series, above every red or purple bed, are alternations of sandstone and pale shale. In one of the shale-beds is a course of small nodules of pyritous ironstone, one of which yielded, on fracture, the fruit in question. It is a mass of bisulphuret of iron, which threatened to fall to pieces; but, having filled its pores with Canada balsam, I hope it may be preserved.

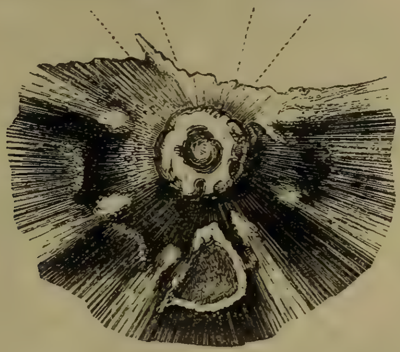
The specimen in question has the form of a compressed ellipsoid. The longest diameter, which coincides with the axis of the fruit, has a length of 0·8 inch, the other two diameters, measured at right angles to this, equal 0·7 and 0·6 inch respectively. The terminal surface is almost completely preserved, the other is only sufficiently traced to show the general figure. The well-preserved terminal surface (fig. 1) exhibits a central ring-like prominence; round this is an obtusely conical surface, slightly granulated, with faint traces of radiating striæ. Round this is a circle of oval prominences. from each of which a conspicuous rib or keel proceeds, in a radiating manner, toward the opposite surface, so as to resemble the meridian of a globe. Eight meridional costæ are clearly traced, occupying the circuit of the fruit symmetrically; six of the prominences at their origin are completely seen, a seventh is traceable, and there is an interval corresponding to another. Thus the fruit is ascertained to have had eight ribs symmetrically disposed.

Between two of the costal prominences, on the flatter side of the

* See Mantell's Geol. South-east of England, p. 246, and Bronn's Leth. Geol. pl. 28, fig. 6, for a representation of *Carpolithus Mantelli*, supposed by Brongniart to be the fruit of *Clathraria Lyellii*.

fruit, is a sort of collar (fig. 1, *c*); its external face is striated;

Fig. 1.—*Fossil Fruit from the Upper Wealden Beds in Swanage Bay. View of the terminal surface, showing the origin of seven ridges, and space for the eighth.* Magnified six times.



*c*. The collar.

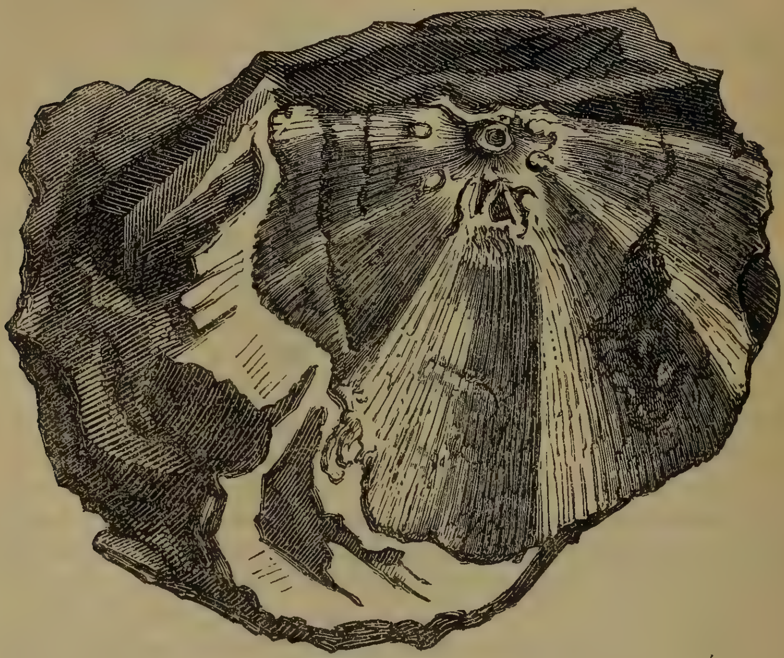
within it, towards the axis, a depression. Between the other prominences a similarly-placed arched depression is traceable, and there seems nothing to prevent the supposition that a similar collar may have existed.

The eight ribs and the intervening hollow surfaces (see figs. 1 and 2) are striated by radiating vessels, which vary in size from $\frac{1}{500}$ to $\frac{1}{1000}$ of an inch in diameter (figs. 3, 4, 5, 6, and 7). They are pressed together, very continuous, occasionally dichotomous; and in this case, the divided vessels lie side by side (figs. 4 and 5). In fig. 5, appears a curious example of this dichotomy both upwards and downwards. They are all jointed at intervals which frequently measure about four diameters of the larger vessels. The surfaces are marked by projections, which, for the most part, appear as mere roughness (figs. 5 and 6), but in a few cases resemble fine oblique parallel striæ, $\frac{1}{3000}$ of an inch apart, and meeting the sides of the tube at an angle of 40° (fig. 7). In other cases they appear as small *puncta*, ranged in one line, at intervals equal to half the diameter of the tube, or scattered in a less regular manner. These last-mentioned observations are difficult, even dubious, and require good single lenses of $\frac{1}{4}$ inch or $\frac{1}{6}$ inch focus to be used for comparison with the results of the compound microscope.

The pyrites appears to be moulded in the cavities of the original vessels, the seeming joints being caused by original transverse plates, and the small projections corresponding to tubular openings and slits in the walls, or to internal depressions having these forms.

The fibrous body is partly surrounded by a thick dark mass of minutely granulated pyrites, which, under the microscope, suggests the question of its being deposited in the cavities of a thick cellular envelope. By an accidental fracture through the pyrites in the part of the specimen opposite to the terminal surface already described, the internal cavity is laid open, lined with finely crystallized bisul-

Fig. 2.—*View of the broader side of the Fossil and its Terminal Surface.* Magnified four times.



Figs. 3 to 7.—*Illustrative of the Structure of the external portion of the Fossil Fruit.*

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

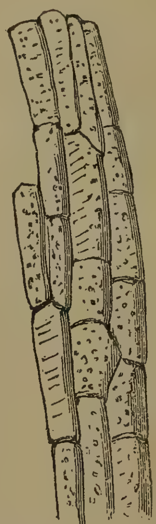


Fig. 7.

Fig. 3.—*Part of the fibrous surface of the Fruit.* Magnified twenty-five times.
Fig. 4.—*Part of the fibrous surface, to show the relative diameters and divisions of the Vessels.* Magnified forty times.
Fig. 5.—*Selected Vessels, to show the dichotomy and the rough or dotted surface.* Magnified seventy times.
Fig. 6.—*Large, rough, or dotted Vessels.* Magnified 100 times.
Fig. 7.—*Obliquely striated Vessel* (*rare*). Magnified 100 times.

phuret of iron. In it, near the base, deep grooves appear (corresponding to the external ribs); two of these are very distinct, and, after passing less than half the length of the interior, cease symmetrically.

By the same fracture the thickness of the shell or crust is discovered, varying from $\frac{1}{40}$th to $\frac{1}{100}$th of an inch. The whole of this substance is fibrous.

In a geological point of view, the more precise determination of several of our fossil fruits appears desirable; especially of the Oolitic and Wealden periods. But this is far from easy. If, for example, we endeavour to trace the analogies of the present specimen, and begin with the great Monocotyledonous groups, we may regard its fibrous mass as having a resemblance to the fibrous pericarp of the *Palmaceæ*. But what Palm gives us a regularly eight-ribbed fruit? What Monocotyledon exhibits such remarkable deviation from the usual tendency to be represented in threes?

Without stopping among the *Coniferæ* and *Cycadaceæ*, which offer in their fruits nothing of this kind for comparison, we may enter the Dicotyledonous groups. Keeping in view the probability of the object being of a firm or woody texture, like a nut, we find in the *Juglandaceæ* some analogies worth notice. For example, the Hickory-nuts have often four stronger meridional ridges alternating with four weaker elevations, corresponding to the quadrilocular interior cavity. The outer covering is four-ridged in *Carya amara*. Ranged among the *Euphorbiaceæ*, in the new Museum at Kew, I find an example of a quadrilocular capsule,—trilocular capsules being common in this order. The plant is from North Australia, and is named *Petalostigma quadrilocularis*. As far as general appearance and character of figure may be appealed to, this fruit is the most like my Swanage fossil. The specimens at Kew show the pericarp to be marked by eight meridional ridges, while the interior divisions of the fruit correspond in number, and separate in octants.

It may, perhaps, here deserve notice, that a spheroidal many-ribbed body, which is usually regarded as a fruit, and was obtained from the lowest part of the Oolitic series on the Yorkshire coast, at Whitby, has been compared with *Hura crepitans*, the Sand-box-nut of the West Indies, which is also Euphorbiaceous (see Young and Bird, Geological Survey of Yorkshire Coast, pl. 1. fig. 5, ed. i., pl. 2. fig. 6, ed. ii.).

I purposely abstain from recording the ineffectual attempts I have made, by my own inquiries, and by consultation with others, to settle the place of this fruit among the natural orders of plants. Probably further search in the same locality will yield additional data, and render it easy to determine what is now found hard to guess.

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April 28, 1858.

James Powrie, Esq., Reswallie, near Forfar, Marcus Huish, Esq., Castle Donnington, Derby, Henry D. M. Spence, Esq., Hyde Park Square, and Parkin Jeffcock, Esq., Derby, were elected Fellows.

The following communications were read:—

## 1. *On some* Vegetable Remains *from* Madeira. By Charles J. F. Bunbury, Esq., F.R.S., F.G.S.

The vegetable remains procured by Sir Charles Lyell and M. Hartung from the leaf-bed which they discovered* in the ravine of S. Jorge, in the Island of Madeira, were entrusted to me for examination ; and I propose now to lay before the Geological Society the observations I have been able to make upon them. I have examined 140 specimens, by far the greatest part of them in a very imperfect state, mostly small fragments, often quite undeterminable, and, even when most perfect, no more than single detached leaves, of which, however, the veins and margin are often very well displayed. Dicotyledonous leaves predominate, but are intermixed with numerous remains of Ferns, always, however, in small fragments, insufficient to give any idea of the general form of the frond. The very fragmentary and incomplete condition of the remains of Ferns in this bed is indeed striking. Something of it is attributable to the nature of the stone, which is by no means fissile, but breaks quite irregularly ; but something also would seem to be owing to the original conditions of the deposit. The circumstance is unfortunate, because Ferns are so variable, and show such differences even in different parts of the same frond, that great uncertainty attends the determination of them from such small fragments.

Of the Dicotyledonous leaves, a large proportion, as I have said, are too imperfect to be even described. Of those that are best preserved, a few kinds may, with a certain degree of confidence, be referred to species now existing in Madeira ; others are manifestly different from any known to exist there ; the rest have, in my opinion, no character sufficiently marked to determine their affinities. On this point, however, I am aware there may be different opinions. Botanists, indeed, are far from being agreed on the question, whether the affinities of Dicotyledonous plants can, as a general rule, be determined from the leaves *alone* ; that is, whether the leaves by themselves afford characters sufficiently definite, and sufficiently in accordance with those afforded by the fructification, to be safe guides to the determination of genera or families. Some eminent palæobotanists of Germany and Switzerland, attaching great importance to the characters of leaves, have assigned generic names to the fossil plants of the tertiary age with a degree of confidence which, in not a few instances, appears rather surprising.

This question cannot be completely settled without a very exten-

* See Lyell's Manual of Elementary Geology, 5th ed. (1855), p. 518.

sive and careful survey of existing families of plants; and to go fully into it, even if I were at present completely prepared to do so, would be too great a digression from the immediate purpose of this memoir. I may observe, however, that, so far as I have hitherto been able to examine this subject, my conclusions are not favourable to the views of the naturalists above referred to. There are but few cases, as it appears to me, in which particular modifications of leaves are distinctly characteristic of natural orders or of natural genera. Certainly, in very many cases, wide variations in the form, venation, texture, and other characters of leaves are observable in the best-defined and most natural groups. For instance, in the Oaks, there are at least *three* distinct and well-marked types of venation:—1st, the *Chestnut* type, in which the *feather-veined** character is shown in the highest degree, and which is exemplified in several of the Himalayan Oaks, such as *Quercus serrata* and *Q. lineata*, and less perfectly in some of the American kinds; 2ndly, the *Oak* type proper, seen in the deciduous-leaved oaks of Europe; and 3rdly, the *Laurel* type, in which the principal lateral veins combine into arches within the margin; this last form prevails in several of the evergreen oaks both of India and of America. Again, in the small and very natural genus *Alnus*, there are two quite distinct types of venation:—the *feather-veined*, in the common Alder, and in the *Alnus incana* and *A. viridis*; the *arch-veined*, in the *Alnus cordifolia* and *Alnus Nipalensis*. So also in the genus *Fagus*: our common Beech and those of North America, and *one* of the antarctic species (*F. Antarctica*), agree in a well-marked type of leaf; but the *Fagus Solandri* of New Zealand and *F. betuloides* of Fuegia have leaves of so different a character, that their affinity to the first-mentioned species could never be inferred from those organs.

We sometimes find certain fossil leaves spoken of as having the characters of the Proteaceous family. Yet, among the *Proteaceæ* that I have examined, the leaves are so various in all respects, that I do not know anything approaching to a common character, unless it be the rigid coriaceous texture; and this, though certainly very general in the order, is scarcely apparent in some, such as *Lomatia dentata*. What is there in common between the leaves of *Leucadendron argenteum* and of *Guevina Avellana*?—or of *Knightia* and any of the Serrurias? Even in the same genus,—how could any one, from the leaves alone, infer the generic identity of *Conospermum longifolium* and *C. ericifolium*?

The family of *Rhamneæ*, another to which many fossil plants have been referred, includes several very distinct types of venation of leaves; and, even in the genus *Rhamnus* itself, the leaves of *Rhamnus catharticus* are materially different in their veining from those of *Rh. Frangula*.

I do not dispute that there are some families and genera of plants which may be easily recognized by characters connected with the

* See Lindley's Introduction to Botany, ed. 1., p. 93. I adopt the terms proposed by this author for describing the venation of leaves.

leaves and their appendages. Such are the *Myrtaceæ**, the *Melastomaceæ*, the *Coniferæ*, the *Rubiaceæ* (*Cinchonaceæ* of Lindley), the genera *Nepenthes*, *Sarracenia*, *Bauhinia*, *Begonia*, *Cinnamomum*, and to a certain extent the genus *Ficus*†. But every botanist who has examined large unarranged collections of dried plants from foreign countries must be aware how difficult it is, in general, to make out the affinities of specimens without fruit or flower, and how often very similar leaves belong to plants of widely different families. This part of the subject has, in truth, been so ably treated by Dr. Hooker in the 10th volume of this Society's Journal, p. 163–165, that it would hardly have been necessary to touch upon it again, were not the confidence with which some eminent foreign geologists assign generic names to mere detached leaves calculated, in my opinion, to mislead the inexperienced; wherefore I have thought it advisable to enter a fresh protest, and to remind geologists of the uncertainty of the evidence we possess.

The imperfect state of our materials must always be borne in mind. When we have before us only detached leaves, as most commonly happens in fossiliferous deposits, and as is the case, in particular, with all the specimens I have seen from Madeira, we lose the benefit of several characters which assist materially in the determination of recent plants: in particular, the character of *insertion* (alternate, opposite, or whorled); and the more important one of the presence or absence of *stipulæ*, and their nature when present. As an example of the importance of these organs, I may notice, that the *Magnolia* family may be easily known, in general, by the peculiarities of the stipules, taken *together* with those of the leaves; but the leaves separately would afford no sufficient indication of the order. The same may be said, still more decidedly, of the *Cinchonaceæ* of Lindley.

Another character, of great use in the determination of recent plants, but almost necessarily wanting in the fossil state, is the nature of the *pubescence*,—the hair, down, scales, or other clothing of the surface.

In those rare cases where the fossil leaves are so well preserved that the cellular structure of the epidermis, and its pores or *stomata*, can be satisfactorily examined, these may probably afford valuable aid towards the determination of affinities. Yet it is a point by no means determined, and one which deserves careful study in recent plants, how far the characters afforded by the epidermis and its pores are in accordance with those of other organs. It is certain, to mention one instance only, that the structure of the epidermis and position of the *stomata* in *Salisburia* are exceptional in the family of *Coniferæ*.

In all that I have said, I have been speaking of the difficulty of determining plants by their *leaves only*. Where fruits of a marked

* The peculiar intramarginal vein of *Myrtaceæ*, however, occurs in several species of other families.

† I purposely omit to mention those genera which consist of only *one* species, such as *Liriodendron*.

form and character occur in company with leaves, and *both* have a strong likeness to those of certain existing families, I do not dispute that the affinities of the plant may very reasonably be inferred from such data, even if the fruits and leaves be not found actually attached to the same branch. Thus I do not doubt that many of the fossil plants from the tertiary beds of Schossnitz in Silesia, described by Professor Goeppert, and many of those from the tertiaries of Œningen, of Styria, and of Croatia, described by Professors Braun, Unger, Heer, and others, are correctly identified. My observations moreover are confined to Phanerogamous plants; in Ferns, the organs of vegetation are certainly of higher systematic importance. Still, on the whole, I cannot help expressing my suspicion, that the fossil remains of plants generally admit of less certain determination, and are of less value in a geological view, than those of animals. I quite concur in the opinion well expressed by the lamented Edward Forbes*, that "the vegetable unit in lists of extinct beings is of far inferior value to the animal unit."

Unfortunately, the vegetable remains hitherto collected from the leaf-bed in Madeira consist solely of leaves, and those detached and imperfect. I shall now proceed to enumerate such forms as I have been able to distinguish among these leaves; referring, whenever I can, to the names given by Professor Heer, in his very able and ingenious paper† on this deposit.

## I. Cryptogams.

1. *Pteris aquilina* (Heer, No. 1. tab. 1–10).

This is by far the most common Fern in the leaf-bed, and occurs indeed in great abundance, but always in very small fragments. Its identity with the recent *Pteris aquilina* (a species very common in Madeira) appears to me very probable. Several of the fragments which I refer to this species appear very different from one another, but corresponding examples may easily be found among the various forms of *Pteris aquilina*.

2. *Woodwardia radicans* (Heer, No. 3. tab. 1. fig. 12).

Of this I have seen only a single leaflet or pinnule, well preserved however, and showing very distinctly the venation, which agrees accurately with that of *Woodwardia radicans*, a well-known native of Madeira. The fossil is very probably identical with that recent species, although the sharp marginal teeth are not so apparent.

3. *Davallia Canariensis* (J. E. Smith)?

A small fragment only, and not very well preserved, but appearing to me to correspond accurately with a portion of the beautiful Hare's-foot Fern, *Davallia Canariensis*, one of the most common ferns of Madeira. Not included in Heer's enumeration.

4. *Aspidium Lyellii* (Heer, No. 7. tab. 1. fig. 15).

Apparently identical with Heer's plant. Our specimen wants the

* Anniversary Address to the Geol. Soc., February 1854, p. 70.

† "Ueber die fossilen Pflanzen von S. Jorge in Madeira; von Dr. Oswald Heer." Read before the Society of Naturalists at Zurich, 5th November, 1855.

fructification, shown in his figure, but on the other hand shows the marginal teeth more distinctly.

5. *Aspidium*?

A fragment of a Fern of very distinct character, but ill-preserved; materially different from any in Heer's list. It has the appearance of an *Aspidium* (*Polystichum*, Presl), of the group of which *Aspidium aculeatum* is the type; and may possibly even be a variety of that species; but does not agree with the form (*Asp. angulare*, Sm.) now existing in Madeira. It comes nearer to the *Aspidium lobatum* of British authors; but perhaps nearer still to *Asp. vestitum*, Swartz.

6. *Nephrodium*??

A fragment too imperfect for determination, but certainly different from any noticed by Heer, may possibly have belonged to some species allied to the *Nephrodium* (*Lastrea*) *Filix-mas*; but I am not able to identify it. Remarkable for the remoteness of the side-veins, in which it differs materially from all the varieties of *Pteris aquilina*, and all the allied species that I have seen; otherwise, in the breadth and position of the leaflets it is not unlike some of the broadest forms of that species.

7. *Nephrodium*?

Another small fragment of a Fern, scarcely admitting of satisfactory determination. Differs from all the varieties of *Pteris aquilina* in the formation of the side-veins, which are perpendicular to the midrib, not recurved, and uniformly once-forked, the bifurcation taking place very near their base; the leaflets too are closely contiguous. The lowest side-veins of every two adjoining leaflets meet *in* the sinus, not *below* it; whereby this is clearly distinguished from *Nephrodium molle*, *N. unitum*, and the rest of that group. Has the appearance of a *Lastrea* or *Polypodium*, but does not well agree with any of those now existing in Madeira.

8. *Adiantum*? *psychodes*, C. B.

A single leaflet (apparently) of a very singular Fern, remarkable for its exact resemblance in shape to a butterfly's wing. The *free* and regularly dichotomous veins lead me to think it a Fern, rather than an insect's wing; and if it be a Fern, it is most probably either an *Adiantum* or a *Lindsœa*, though materially different from any that I know.

### II. Monocotyledons.

9. *Cyperus*?

A fragment of a leaf, evidently belonging to some large Grass or Cyperaceous plant; more probably the latter. The strong sharp keel, parallel margins, and numerous fine parallel veins are characteristic.

### III. Dicotyledons.

10. *Laurus Canariensis* (Webb and Berthelot)?

The most abundant dicotyledonous leaves in the S. Jorge bed appear to belong to a kind of laurel,—perhaps to more than one. Heer has referred them to the *Oreodaphne fœtens*, Nees (*Laurus fœtens*, Aiton), or Til tree; but the most perfect of the specimens in the collection before me have, as it appears to me, a greater likeness to the *Laurus Canariensis*, Webb. This, like the Til, is a very abundant tree in the recent forests of Madeira. The most striking character of the fossil leaves in question consists (as Heer has already remarked) in the presence of certain little pits in the axils of the lower primary veins, on the under side of the leaf, and of corresponding protuberances or swellings on the upper side. In this point they agree both with *Oreodaphne fœtens* and with *Laurus Canariensis*; but the general shape and size of the leaves, and the venation in general, in our best specimens, appear to me to correspond best with the latter*. I am inclined to think, however, that *both* occur among the S. Jorge plants. At the same time I must say, that I have not seen one specimen sufficiently perfect to satisfy me completely as to its specific characters; those which are best preserved as to outline do not exhibit the veining with sufficient distinctness. The pits in the axils of the veins, though a striking character, are not confined to the two species I have mentioned, for I find similar pits in the leaves of at least two Brazilian species of the same natural order.

11. *Oreodaphne fœtens* (Heer, No. 12. tab. 2. fig. 4–14).

Some very ill-preserved specimens in the collection before me appear to agree with Heer's description and figures here quoted, especially with his fig. 12. They differ from the leaves that I have referred to *Laurus Canariensis*, principally in having the two lowest primary veins nearly opposite to each other, and remarkably strong, so as almost to give a triple-ribbed character to the leaf. In this they agree with the *Oreodaphne*, and not with the *L. Canariensis*. The network formed by the ultimate veins is somewhat different in the two species, being more minute and uniform in the *Laurus Canariensis*; but none of the fossil specimens that I have seen are satisfactory in this respect. The fossil flower represented by Heer (fig. 14) seems to agree with that of *Oreodaphne*; I find nothing similar among our specimens.

12. *Corylus australis* (Heer, No. 10. tab. 2. fig. 1, 2).

Specimen very incomplete; but its remarkable and well-preserved venation agrees exactly with that of Heer's plant.

13. *Salix* ? ?

A leaf, which, by its narrow linear lanceolate form, reminds us of the Willows, and may possibly belong to that genus; but it has the appearance of a thicker and more coriaceous texture than is usual in willows, and on the whole has, I think, more resemblance to some of the narrow-leaved *Myrtaceæ*, such as *Metrosideros angustifolia*. The veins are ill-preserved. It does not agree exactly with Heer's *Salix Lowei*.

* *Laurus Canariensis*, however, varies considerably in the shape of its leaves. The pits in question are particularly conspicuous in the Azorean specimens given me by Mr. Watson.

14. *Myrtus*? (*M. communis*, Heer, No. 17. tab. 2. fig. 21, 22).

Appears to have the characteristic venation (though not perfectly well preserved), as well as the other characters of a Myrtle leaf. It is probably what Heer has called *Myrtus communis*, but is distinguished by its very obtuse apex from all the varieties of *Myrtus communis* that I have ever seen.

15. *Vaccinium Maderense* (Heer, No. 15. tab. 2. fig. 15, 16).

All the specimens of this that I find in Sir C. Lyell's collection are very incomplete, but agree well, so far as they go, with the species to which they are referred by Heer, the *Vaccinium padifolium*, Sm., or *Maderense*, D.C.

16. *Vaccinium Myrtillus*?

A small leaf, well preserved, agreeing accurately with the leaf of the common Whortleberry, *Vaccinium Myrtillus*; a species not now found in Madeira.

17. *Erica arborea* (Heer, No. 14. tab. 2. fig. 17).

These leaves have so little marked character, that the identification, though very possibly right, does not appear to me quite certain.

18. *Ilex Hartungii* (Heer, No. 18. tab. 2. fig. 23, 24).

The evidence on which this leaf is referred to the genus *Ilex* does not appear to me very conclusive.

19. *Pittosporum* (Heer, No. 21. tab. 2. fig. 27).

Our single specimen of this agrees exactly with the fragment figured by Heer, but throws no additional light on the affinities of the plant, which, to say the truth, appear very uncertain.

20. *Phyllites hymenæoides*, C. B.

A leaf remarkable for its very oblique or unequal-sided shape, which gives reason to believe that it is a lateral leaflet of a pinnated or trifoliate leaf. It is very entire at the margin, obtuse at the apex; the surface appears to have been very smooth and even, no veins visible except the midrib. Has a general resemblance in form to the leaflets of certain tropical *Leguminosæ*, such as various species of *Cassia*, *Hymenæa*, and *Copaifera*. I do not know, in the existing Flora of Madeira, any indigenous plant with leaves at all resembling this fossil. The *Cassia bicapsularis* is undoubtedly an introduced plant in that island, and moreover its leaflets have but a distant resemblance to the specimens now under consideration.

21. *Phyllites lobulata*, C. B.

Another leaf which appears, from its obliquity and irregularity of form, to have been a leaflet of a compound leaf. It is very oblique, and has a remarkable lobe *on one side only*. This sort of irregularity is like what is occasionally to be seen in the lateral leaflets of the *Anacardiaceæ*; but I do not know any that it exactly resembles.

22. *Phyllites*.

A leaf of an obovate-elliptical form, rounded at the end, with very entire margins, and venation of the most ordinary Dicotyledonous type. Has no marked characters, but perhaps most resembles the leaf of some Honeysuckles, such as *Lonicera Caprifolium* and its allies. Not figured by Heer.

23. *Phyllites.*

A small leaf, which I cannot identify; its chief character is the very acute point into which it tapers from a broad somewhat cordate base; the margin very entire.

I will add, for the sake of comparison, a list of the species enumerated by Professor Heer, as determined by him among the fossil leaves from the same bed:—

1. Pteris aquilina, *L.*
*2. Trichomanes radicans, *Sw.*
3. Woodwardia radicans, *Sm.*
*4. Osmunda regalis, *L.*
*5. Asplenium marinum, *L.*?
*6. Asplenium Bunburianum, *Heer.*
*7. Aspidium Lyellii, *Heer.*
*8. Salix Lowei, *Heer.*
*9. Myrica Faya, *L.*
10. Corylus australis, *Heer.*
*11. Ulmus suberosa, *Mœnch.*
12. Oreodaphne fœtens, *Nees.*
*13. Clethra arborea, *L.*
14. Erica arborea, *L.*
15. Vaccinium Maderense, *D.C.*
*16. Vinca major, *L.*?
17. Myrtus communis, *L.*
18. Ilex Hartungii, *Heer.*
*19. Rhamnus latifolius, *Héritier.*
*20. Pistacia Phæacum, *Heer.*
21. Pittosporum ?
*22. Rosa canina, *L.*?
*23. Psoralea dentata, *D.C.*
*24. Phyllites (Rhus?) Ziegleri, *Heer.*
25. Grass, undetermined.

Of the 25 forms in this list, as many as 13† are wanting in mine, namely the Nos. 2, 4, 5, 6, 9, 11, 13, 16, 19, 20, 22, 23, 24. The determinations of some of these are acknowledged by Heer himself to be very doubtful. Six out of the thirteen are identified by him with species now existing in the island, namely the *Trichomanes*, *Asplenium marinum*, *Myrica*, *Clethra*, *Vinca* (doubtful), *Rosa* (very doubtful). Four others are considered to belong to existing species *not* now found in Madeira,—the *Osmunda*, *Ulmus*, *Rhamnus*, and *Psoralea.* The three remaining kinds appear to be extinct

On the other hand, I find in the collection before me 11 forms which are not in Heer's list; these are—

Davallia Canariensis ?
Aspidium ? (No. 5 of my list.)
Nephrodium ? (No. 6.)
Nephrodium ? (No. 7.)
Adiantum psychodes ?
Cyperus ? (No. 9.)
Vaccinium Myrtillus ?
Phyllites (No. 20 of my list.)
——— (No. 21.)
——— (No. 22.)
——— (No. 23.)

The total number of distinguishable forms in the two collections thus amounts to 36; but the greater part of them must be considered as very imperfectly known, and too uncertain to afford safe ground for any botanical conclusions. I will, however, hazard a few observations on the materials thus collected.

1. The most abundant of the Dicotyledonous leaves, and the most abundant of the Ferns, are with great probability identified with species now existing in the island. The Fern, *Pteris aquilina*, is indeed a plant which has a wide geographical range, and accommodates itself to a variety of conditions; but not so the two Laurels, *Laurus Canariensis* and *Oreodaphne fœtens*, which appear to be confined to the three Atlantic groups of islands, the Madeiras, Canaries,

† Perhaps the *Salix Lowei*, No. 8, should be added.

and Azores. If the identification be correct, the abundant presence of these two species may perhaps allow us to infer (though certainly not with absolute confidence) that the conditions of climate of the island in the time of the S. Jorge deposit were not very widely different from those now existing. This conclusion will be strengthened if the leaf referred to *Vaccinium Maderense* (No. 15) really belonged to that species; for that *Vaccinium* appears to be at present confined to the island of Madeira*. Besides the *Pteris*, two other Ferns of the leaf-bed seem to be very probably identical with species now very abundant in the island, the *Davallia Canariensis* and the *Woodwardia radicans*. The present geographical range of the *Davallia* is tolerably well defined, and not very extensive, though more so than that of the laurels and whortleberry above mentioned; it is found in the Madeira and Canary islands (*not* in the Azores), in the north-western part of the African continent, the south-west of Spain and Portugal. Of the *Woodwardia*, the distribution is so peculiar and so difficult to explain, that no conclusions can safely be drawn from it.

The presence of the *Erica arborea*, if the leaves No. 17 be rightly referred to that species, is another point of agreement between the recent vegetation of the island and that preserved in the deposit of S. Jorge; for the abundance of that heath is a well-known and striking feature of the Madeira forests. The *Erica arborea* has a wider range than the laurels and whortleberry already mentioned; it is apparently general in the countries bordering on the Mediterranean.

2. Certain other forms in our list, such as the *Corylus australis* of Heer, the leaves No. 20 and No. 21, and the *Adiantum ? psychodes*, are distinctly different from any now existing, at least in Madeira or the neighbouring islands, and appear to belong to extinct species; but it is not impossible that their extinction may have taken place within the human period.

3. None of the fossils can be said to belong distinctly and positively to tropical families. The leaves No. 20 and 21 may perhaps indicate something of a tropical character of vegetation, but by no means unequivocally.

4. Those forms, among the fossils, which are different from the present vegetation of Madeira do not show any marked analogy to any other existing Flora. The extinct vegetation preserved in some of the Tertiary strata of Europe shows a striking resemblance to the existing vegetation of North America; this certainly cannot be said of the S. Jorge plants.

5. Webb and Berthelot remark that the general character of the forest-trees of the Canary Islands is to have smooth, glossy, coriaceous leaves, undivided, and either entire or at most finely serrated at the margin. The same observation is equally applicable to the forest-trees of Madeira. Now in this respect the fossil leaves of S. Jorge show, on the whole, a considerable analogy with the recent vegetation; for

* Unless the *Vaccinium cylindraceum* of the Azores be the same species, as Mr. Watson thinks.

there is among them a decided predominance of undivided and entire-edged leaves, with smooth (not wrinkled) and glossy surface.

6. The intermixture of abundant remains of Ferns with those of Dicotyledonous plants is a characteristic of this leaf-bed. In the plant-bearing deposits of the palæozoic and secondary periods, the Ferns are generally found unaccompanied by any trace of ordinary (*angiospermous*) Dicotyledons; in those of Tertiary age, this latter class prevails, and Ferns are for the most part rare or wanting. The intermixture of both classes is perfectly analogous to the existing state of things in Madeira. The profusion of Ferns in the under-growth of the forests of that island is well known to all who have travelled there, and we should certainly expect their remains to be preserved in any fossiliferous freshwater deposit that might be formed in such a country.

7. The leaf-bed of S. Jorge has undoubtedly preserved to us but a very small fraction of the vegetation which at the time clothed the island; and a variety of causes, difficult to estimate, may have influenced the proportions in which different kinds of plants were preserved; therefore it would hardly be safe to draw any conclusions from the very small proportion of *Monocotyledons*, whether in this collection or in that described by Professor Heer. This is, however, a fact deserving of notice. It is not merely that the proportion of distinct forms belonging to that class is extremely small, but that their remains are extremely scarce. Now, Grasses and *Cyperaceæ* would seem very likely plants to be preserved in any freshwater deposit, as they so often grow near water, and their leaves, from the quantity of silex they contain, seem well fitted to resist decomposition. That the leaves of these plants may, in fact, be preserved in a fossil state, is shown by the discovery of several fossil kinds in the Molasse of Switzerland. (See Gaudin and De la Harpe.) It is, perhaps, worth notice, that the proportion of *Cyperaceæ* in the existing Flora of Madeira appears to be remarkably small. This cannot, however, be said of the Grasses.

8. On the whole, I am disposed to conclude that the vegetation of Madeira, at the time when the S. Jorge leaf-bed was formed, was, though not absolutely identical with that now existing, yet not very different from it. But such conclusions must be received with great caution, considering the small extent of the deposit, and how imperfectly it is yet known.

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## 2. *On a* Section *of a part of the* Fifeshire Coast. By the Rev. Thomas Brown.

(Communicated by Sir R. I. Murchison, V.P.G.S.)

[Abridged.]

This section of the Carboniferous strata, as exposed on the northern shore of the Firth of Forth, from Anstruther to Burntisland, represents the strata, at about high-water mark, arranged as occupying the space due to their real thickness only.

The Carboniferous rocks in this section present three great natural groups:—1, the Lower Carboniferous; 2, the Mountain-limestone; and 3, the Upper Carboniferous, or the workable coal-measures.

From Anstruther, on the east, to beyond Pittenweem the sequence of strata is clear, exhibiting a magnificent series of the Lower Carboniferous rocks (approximately 3800 feet thick), consisting of freshwater or estuarine shales and sandstones, with a few bands of limestone, one of which latter is of marine origin. The comparative abundance of *Sphenopteris affinis* characterizes the upper portion of this inferior group; and of *Cyclopteris*, its lower portion. The Burdiehouse limestone belongs to the upper portion; and, like the other calcareous bands, gets thinner eastwardly. The Granton beds, on the contrary, appear to belong to the lower portion.

The lowest portion of this Lower Carboniferous series has *Cyclopteris, Stigmaria, Carpolithes*, and *Cypridæ*. The marine band—an argillaceous limestone, in the middle of the series—has *Encrinites, Fenestella, Nucula tumida, N. attenuata*, and *Productus semireticulatus*. The upper half of the series contains *Sphenopteris affinis, Cypridæ* in abundance, and *Palæoniscus*.

The strata have a westward inclination, with a gradually increasing angle of dip, which is still greater towards St. Monance, as the section traverses the "Mountain-limestone" series. This consists of sandstones and shales, with five or six beds of limestone—all of marine origin, and may be altogether about 400 feet thick. The lowest of these bands of limestone (at Ardross) contains *Nucula tumida, N. attenuata, Schizodus sulcatus, Goniatites, Natica, Serpulites, Holoptychius Hibberti, Eurypterus* (?), *Gampsonyx, Dithyrocaris*. The next band (E of the section) and its accompanying "bone-bed" contain *Productus semireticulatus, Aviculopecten, Spirifera duplicostata, Cochliodus, Ctenacanthus, Pterichthys* (?), and *Eurypterus*.

The fossils of the four limestone-bands (D, C, B, A) in the upper part of the "Mountain-limestone" are *Zaphrentis, Orthis filaria, Productus punctatus, P. semireticulatus, Aviculopecten, Modiola, Loxonema rugifera, Orthoceras*, and *Nautilus subsulcatus*.

This "Mountain-limestone" series passes under the Coal-basin (Upper Carboniferous) of St. Monance*, reappearing with a reversed dip. Between St. Monance and Elie the strata are associated with much trap-rock, and are singularly contorted: and an important fault runs parallel with the coast, causing much confusion. At Elie the beds have a westerly dip, and pass under the great central coal-basin of Fife†. This consists of upper carboniferous rocks, estimated by Mr. Laudale at 1700 feet in thickness.

* See Mr. Laudale's description, Transact. Highland Soc. vol. xi.

† Including the coal-fields of Dysart, Wemyss, Leven, Largo, and Earlsferry. See Mr. Laudale's Memoir in the Transact. Highland Soc. vol. xi.

At Invertiel (Kirkaldy) the "Mountain-limestone" beds reappear from under the coal-measures with an easterly dip; and the section crosses the lower shales, sandstones, and limestone, with thick intercalated trap-rocks, all having the same general inclination, to Burntisland, where a lime-band crops out, which is equivalent to that of Burdiehouse, and on the same level with that near Pittenweem, above mentioned.

*Details of the Section,—commencing on the West.*

| | | | |
|---|---|---|---|
| Lower Carboniferous. | Shales and sandstone . . . . . . . . . . | Burntisland. | Dip easterly. |
| | Limestone-band (K) and sandstone. | | |
| | Trap-rock . . . . . . . . . . . . . | Pettycur Harbour. | |
| | Limestone (H); trap-rock, with thin interstratified shales. | | |
| | Trap-rock. | | |
| | Covered ground; and sandstone and shale . | Kinghorn. | |
| | Thick conformable trap-rocks, with occasional shales and sandstones. | | |
| Mountain-limestone. | Bone-bed, shale, and limestone (E). | | |
| | Conformable trap-rock. | | |
| | Shale; limestone (D); sandstone and shale. | | |
| | Conformable trap. | | |
| | Shale and sandstone; bed of trap; shale and sandstone; and limestone (C) . . . . . | Seafield Tower. | |
| | Shales and sandstones. | | |
| | Limestone (B); shale and sandstone; sandstone; limestone (A); conformable trap . | Invertiel (Kirkaldy). | |
| | (Upper Carboniferous omitted.) | | |
| Mountain-limestone. | Limestone-band (A). Sandstone . . . . . . . . . . . . . . . . . . | | Dip westerly, at a low angle. |
| | Trap-rock . . . . . . . . . . . . . . | Elie Pier. | |
| | Inclined and arched strata of sandstone and shale, and the limestones B, C, D, and E, with interpolated masses of trap-rock. | | |
| | Encrinites in B and C; shells in D; Encrinites, Corals, Shells, and Fish-teeth in E and its shales . . . . . . . . . . . | Saucher Point, Ladies' Tower. | |
| | [At one spot the lower beds with *Sphenopteris*, *Megalichthys*, &c. are brought up by a fault.] | | |
| | Shales and sandstones, with a thin limestone (F), in a succession of irregular anticlinal and synclinal folds, with interruptions of trap. Encrinites in the band F at Newark Castle; and *Holoptychius Hibberti* and *Dithyrocaris*, at Ardross Castle . . . . | Ardross and Newark Castles. | |
| | [In the axial fold, to the west of Newark Castle, a shale-band (G), with *Sphenopteris affinis*, *Cypridæ*, and Fish-remains, is brought up. Lower Carboniferous.] | | |
| Mount. limest. | Trap-rock. | | |
| | Sandstones and shales, with thin fossiliferous limestones E, D, C, B, and A . . . . . . . . . . . | | Dip easterly. |
| | (Upper Carboniferous omitted.) | | |
| Mount. limest. | Shales and sandstones, with thin bands of limestones (A—F) containing Encrinites, Corals, Shells, &c. | | |

| | | |
|---|---|---|
| Lower Carboniferous. | Shales and sandstones, with a shale-band (G) containing *Sphenopteris affinis*, and lower down a thin limestone (H) with *Sphenopteris* and *Cypridæ*. | Dip westerly. |
| | Sandstones and shales. | |
| | Shale and a limestone-band (K). *Sphenopteris affinis* abundant. | |
| | Sandstones and shales . . . . . . . . . | Pittenweem Harbour. |
| | Shale with a calcareous band (L). Encrinites, Corals, and Shells. | |
| | Shales and sandstones. *Sphenopteris* in some of the uppermost; *Cyclopteris* abundant in several of the shales. | |
| | Shale and limestone-band. *Cyclopteris* and Fish-remains. | |
| | Sandstone and shale. | |
| | Shale with a limestone. *Cyclopteris* and *Carpolites*. | |
| | Sandstones and shales, with a bed of trap-rock. | |
| | Shale with a thin limestone, containing Fish-remains, *Cypridæ*, and *Cyclopteris*. | |
| | Sandstones, shales, and bedded trap-rock. Fish-remains in one of the shales. | |
| | Sandstones and shales, with a seam of coarse coal, and two thin calcareous bands in the shales. Casts of *Stigmaria* abundant in the lower sandstone. | |
| | (Covered ground.) | |
| | Sandstone . . . . . . . . . . . . . . | Anstruther West. |
| | Sandstone and shales. | |
| | Shale. | |
| | Sandstones and shale . . . . . . . . . | Anstruther Harbour. |
| | [Further eastward the same strata are repeated, with reversed dips.] | |

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3. *On the* Lower Coal-measures, *as developed in* British America. By J. W. Dawson, LL.D., F.G.S., Principal of McGill College, Montreal.

Deposits indicating the existence of the coal-flora and its associated freshwater fauna at the beginning of the Carboniferous period have been recognized in various parts both of the Old and New Worlds, and have modified the views entertained of the subdivisions of the Carboniferous system. In Nova Scotia and New Brunswick such deposits are developed with a clearness and fullness of detail capable of throwing much light on the dawn of the terrestrial conditions of the coal-period, and on the relations of these lower beds to the true coal-measures. I propose in the present paper to offer a contribution towards this end, by collecting in one view the information existing on these rocks in British America, with the addition of facts collected in the past summer, and the results of a comparison of the specimens in my collection with those of the upper portions of the coal-measures.

I. *Characters and extent of the Lower Carboniferous Rocks.*

The occurrence of beds containing coal-plants in connexion with the Lower Carboniferous marine deposits of Nova Scotia was observed by Sir W. E. Logan in 1841, though at that time the true place of the beds was not understood, owing to the belief that the limestones afterwards ascertained to be Lower Carboniferous were of Permian date. Sir C. Lyell examined these beds in 1842, as they occur at Horton Bluff; and the author subsequently more fully examined their relations to the marine limestones, and traced them in various parts of Nova Scotia, and at the Albert Mine in New Brunswick*.

This series may, in general terms, be characterized as consisting of shales and sandstones destitute of marine shells, and containing fossil plants, fishes, and entomostracans, locally underlying the great marine limestones and gypsums of the Lower Carboniferous series, and separated by these from the true coal-measures, from which they are also in some respects distinguished by mineral character and fossil remains. I have said *locally* underlying the marine limestones, because I believe that in some places they are strictly contemporaneous with these, forming estuary-, lagoon-, and swamp-deposits at their margins.

To avoid repetition of details previously given, I have thrown into a tabular form the structure of this part of the Carboniferous system, as it appears in some of the best exposures. I have in this table slightly modified the names proposed in former papers for the subdivisions of the system, calling the true productive coal-measures the *middle*, instead of the *lower* series, and transferring the latter term to the beds described in this paper, formerly described as pseudo-coal-measures underlying the carboniferous limestones.

The first and second columns in the annexed Table represent the structure of this formation in the western part of Nova Scotia, where the true coal-measures and upper coal-measures are scarcely, if at all, developed, and where the lower carboniferous marine deposits attain their greatest thickness. I had an opportunity in June last of re-examining the best sections of this part of the province, in company with Dr. Harding and Professor How, of Windsor, and the Rev. Mr. Rand, of Hantsport. At Horton Bluff, several faults oppose some difficulties to an accurate measurement of the thickness; but I have estimated these strata at 600 feet in all, apparently destitute of true marine remains, and marked lithologically by a great proportion of dark and grey sandstones and shales. From the localities mentioned in the Table, these beds may be traced along the margin of the metamorphic country as far as the Shubenacadie River, and probably as far as the valley of the Steiviocke, fifty miles distant from Horton. They reappear along an anticlinal line parallel to the former, at Walton, Noel, and other places on the coast of the Bay of Fundy†. The intervening trough is filled with the marine limestones and the accompanying marls, red sandstones,

* Quart. Journ. Geol. Soc. vol. i. p. 31; iv. p. 59; v. p. 335; vii. p. 398; ix. p. 107.

† Quart. Journ. Geol. Soc. vol. vii. p. 389.

*Tabular view of the Lower Coal-measures of British America.*

| Groups. | Horton. | Mill Brook, Windsor. | Hillsborough, New Brunswick. | Plaister Cove, Cape Breton. |
|---|---|---|---|---|
| Upper Coal-measures. | Not seen. | Not seen. | Upper sandstones and shales of South Joggins. | Not seen. |
| Middle Coal-measures. | Not seen. | Not seen, unless represented by the coal-measures of Kennetcook River. | Coal-measures of Joggins, and millstone-grit or Lower Coal-measures of Dorchester, &c. | Coal-measures of Caribou Cove, River Inhabitants, and Ship Harbour. Sandstones of Strait of Canseau. |
| Lower Carboniferous Marine Limestones. | Limestone, marl, red sandstone, and gypsum of Halfway River and Windsor. | | Limestones, gypsum, and conglomerate of Dorchester and Petitcodiac River. | Limestone, gypsum, and marls of Plaister Cove. |
| Lower Coal-measures. | Dark clay-shale and calcareous shale, with laminated limestone, dark micaceous flags, grey and white sandstone, and in the lower part some red sandstone.<br>Plants, Fishes, Entomostracans, worm-tracks, ripple- and rain-marks, sun-cracks, reptilian footprints, erect trees. Lower Horton, Wolfville, Horton Bluff, Halfway River.<br>(See Paper by Sir C. Lyell, Quart. Journ. Geol. Soc. vol. iv. p. 184; Paper by the author, ibid. vol. iv. p. 59.) [Observed by the author in 1857.] | Thick white sandstone (debris of white granite), in places with quartz-pebbles. Fragments of plants.<br>Dark micaceous flags and shales, obscure footprints, carbonaceous impressions, an underclay, a thin ironstone, grey coarse sandstone and conglomerate, white sandstone, carbonaceous shale, and black underclay.<br>Near the bottom irregular and shore-like layers of coarse sand in the shale. *Lepidodendra.*<br>(See Paper by Sir C. Lyell.) [Observed by the author 1857.] | Fine calcareous and highly bituminous shales, with thin beds of sandstone. Abundance of remains of fishes, seen at Petitcodiac River, above Dorchester, Albert Mine, and other localities westward of that place.<br>(See Paper by the author, Quart. Journ. Geol. Soc. vol. ix. p. 107.) | Hard sandstones and shales, of grey and black colours, with obscure fragments of plants, resting on coarse grey conglomerate, of great thickness.<br>(See Paper by the author, Quart. Journ. Geol. Soc. vol. v. p. 335.) |
| Underlying rocks. | Upper Silurian slates, unconformable. | Hard thick-bedded rock, resembling an indurated volcanic ash. No fossils. Age uncertain. | Metamorphic rocks of uncertain age, in the coast-range of New Brunswick. | Slates, &c. of Cape Porcupine, &c. Probably Upper Silurian. |

and gypsums, with the exception of a limited space near the Kennet-cook and Five-mile Rivers, occupied by beds which, perhaps, represent the middle coal-measures. These two lines of appearance run in a north-eastern and south-western direction, and are distant ten or fifteen miles from each other. The waters of Cobequid Bay and Minas Basin, perhaps, fill another synclinal trough, which, however, in the upper and narrower end of the bay appears merely as a depression along an anticlinal axis; and we do not observe the lower coal-measures again until they are thrown up, in a very disturbed condition, along the south side of the Cobequid Mountains, where we have another line of outcrop, running east and west. Here they appear as a continuous belt, eighty miles in length; but it is not easy to establish any boundary between them and the true coal-measures, which are also present*.

This appears to arise from the slender development of the marine parts of the system near the mountains, and the disturbed condition of the whole. These hills, indeed, appear to have retained their position during the whole coal-period; and semiterrestrial conditions prevailed along their south side during the time when the marine limestones were being formed at a greater distance from their base. Hence in some localities, as at Folly River, we have the coal-measures approaching the base of the hills, and underlaid by conglomerates without any marine limestones, while, at a greater distance from the hills, the marine limestones arise from beneath these same coal-measures. In other places, as at the North River, the limestones appear under the coal-measures, or at least the greater part of them; and, again, at Salmon River a limestone with encrinal remains appears to be inserted in the midst of true coal-measures.

This original irregularity of deposition is now complicated by a multitude of fractures. The best section that I have had an opportunity of examining, in this district, is that of Folly River, which appears to show, at the base of the Carboniferous system, in descending order—

| | Estimated thickness. |
|---|---|
| 1st. Reddish and grey sandstones with a bed of conglomerate .......................... | 300 feet. |
| 2nd. Dark shales and grey sandstones, with thin coaly layers, containing *Poacites* and *Stigmaria*, and probably representing the lower coal-measures ........................ | 200 ,, |
| 3rd. Coarse conglomerate, containing fragments of the metamorphic rocks of the hilly range on which it rests ..................... | 450 ,, |

There seems no reason to doubt that the shales in this section correspond with the Horton Bluff series, and the conglomerate with the sandstones which underlie that series.

Along the northern side of the Cobequid Range, and its eastern

* Quart. Journ. Geol. Soc. vol. iv. p. 52.

continuation in the Pictou Coal-field, I have observed no definite development of the beds now under consideration; but the middle and upper coal-measures attain a very great importance, and the marine limestones, red sandstones, and conglomerates are of great thickness, and appear to rest directly on the older metamorphic rocks*.

On the northern side of the wide carboniferous trough of Cumberland, the beds (in the third column of the table) are thrown up along an anticlinal, and represent the lower carboniferous coal-measures in position and fossils, though in some respects different in mineral character. They are remarkable for their highly bituminous composition, the presence of fishes in a very perfect state of preservation, and the almost entire absence of plants. Deposits corresponding to those of the Albert Mine appear to extend to the westward for a considerable distance along the south side of the coal-field of New Brunswick.

On the northern side of that coal-field, on the Baie de Chaleur, Sir W. E. Logan describes† great beds of calcareous conglomerate, alternating with red and drab-coloured sandstone and shale, as forming the base of the Carboniferous system. These beds, amounting to a thickness of 2766 feet, afforded no marine fossils; but some of the beds contained carbonized remains and casts of plants‡; so that, though the physical conditions here are different from those of the lower coal-measures of Nova Scotia, the land rather than the sea appears to have afforded the few fossils present in the beds, which, except in their greater thickness, are not very dissimilar from the lower conglomerates of Pictou, Cumberland, and Cape Breton.

The sections represented in the fourth column of the table show the most distinct exposures observed in Cape Breton and the extreme east of Nova Scotia, where I have described a small series of similar character as occurring at Right's River, near Amtigonish: the sandstones and shales of the valley of the St. Mary's River must also belong to this part of the system§.

In Nova Scotia these older coal-measures, as compared with the true coal-measures, are more calcareous, abound more in remains of fishes, and have fewer vegetable remains and indications of terrestrial surfaces. They occur generally along the margins of the coal-areas, near their old shores; and, as we might expect in such circumstances, they are associated with, or replaced by, beds of conglomerate derived from the neighbouring highlands, of Silurian and Devonian rocks. Where these conglomerates are absent, we usually find very frequent alternations of sandstones with sandy and calcareous shales, giving a homogeneity of appearance, together with, at the same time, very frequent changes and differences in fossil character. The general aspect is that of muddy estuarine deposits, very slowly

* Quart. Journ. Geol. Soc. vol. i. p. 272.

† Quart. Journ. Geol. Soc. vol. iii. p. 350.

‡ The only well-characterized fossil plant obtained by Sir W. E. Logan from these beds, is a *Caulopteris*, closely resembling *C. primæva*, Lindley and Hutton.

§ Report of Geol. Survey of Canada, 1845.

accumulating, and discoloured and darkened by decaying organic substances, partly of aquatic, and partly of terrestrial origin.

Both the supply of sediment and the growth and preservation of vegetable matter were on a smaller scale than in the true coal-period, the only exception being the bituminous limestones and associated dark shales of the latter, which in composition and aspect often much resemble the beds now under consideration.

These characters cause the Lower Carboniferous coal-measures to present a very striking contrast with the coarse and often reddish sediments which prevail in the marine parts of the Lower Carboniferous series in the area in question.

Before leaving this comparative view, it is necessary to remark that it is precisely in those districts where the true coal-measures are least developed that the lower series is most important. This is not likely to be the result of accident. It shows that the physical and vital conditions of the coal-measures originated as early as those of the mountain-limestone, that locally these conditions may have been contemporaneous throughout the whole period, but that in some localities the estuary- and swamp-deposits first formed were so completely submerged as to be covered by oceanic deposits, while in others early marine beds were elevated and subjected to the conditions of gradual subsidence and vegetable growth indicated in the great coal-measures of South Joggins, Pictou, and Sidney.

II. *Flora of the Lower Coal-measures.*—In Nova Scotia the lower coal-measures are characterized by a great preponderance of *Lepidodendra*, and the leaves named *Poacites*, among their fossil plants. The middle coal-measures are rich in *Sigillariæ* and Ferns as well as *Lepidodendra*; and the upper coal-measures especially abound in *Coniferæ*, *Calamites*, and Ferns. These peculiarities may be local and dependent on the facilities for the preservation of particular kinds of plants; but they deserve more attention than they have hitherto received, in connexion with the changes of physical condition which have occurred during this long period, and with the accumulation of the largest beds of coal in the middle coal-measures. It must be confessed that the flora of the lower coal-measures is by no means rich in species, though locally, as at Horton Bluff and Windsor, there are great numbers of individual plants.

1. *Lepidodendreæ.*—In this group of plants *Lepidodendron elegans* takes precedence as the most abundant species. At Horton and Windsor there are large numbers of prostrate trunks and branches, sometimes with the leaves attached. In two distinct beds there are erect stumps, apparently referable to this species. They are of small size, but very numerous, and must have constituted dense groves of these trees. Their roots appear to have been branching and fibrous; and no trace of *Stigmaria* was found in the underclays. These trees must have grown in sandy clay; and beds with fishes and ripple-marks occur at no great distance both below and above them. The quantity of prostrate trunks and branches overlying one of these fossil forests would appear to indicate that the trees

had been violently broken off. These are the only beds containing erect trees that I have observed in the lower coal-measures; and one of them was observed for the first time in 1857.

Figs. 1, 2, 3.—*Surface-markings of* Lepidodendra *from the Lower Coal-measures of Nova Scotia.*

Fig. 1 *a*. Fig. 2 *a*. Fig. 3 *a*.

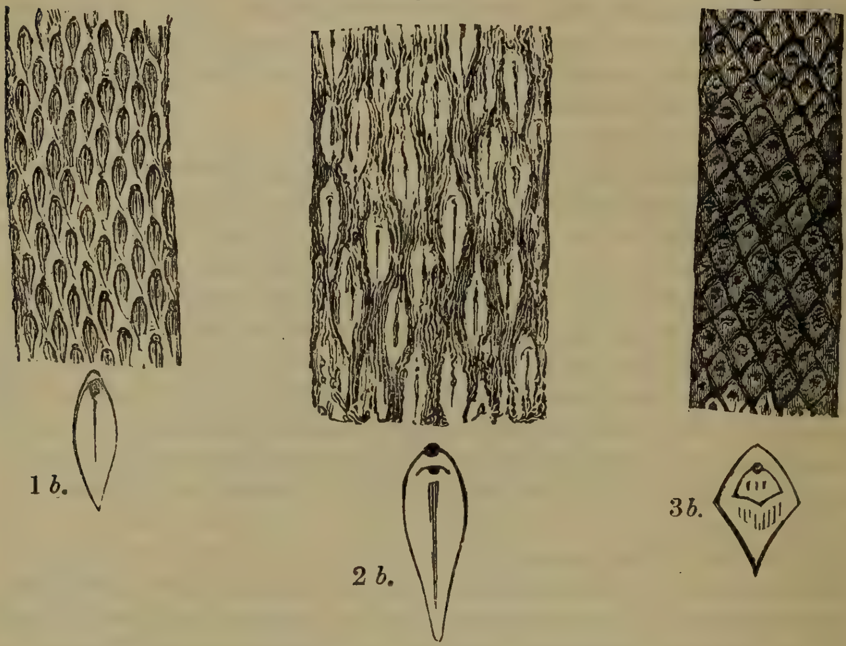



Fig. 1 *a*. Lepidodendron elegans.
Fig. 1 *b*. Areole and leaf-scar.
Fig. 2 *a*. Lepidodendron corrugatum.
Fig. 2 *b*. Areole and leaf-scar.
Fig. 3 *a*. Lepidodendron Sternbergii.
Fig. 3 *b*. Areole and leaf-scar.

A second species, rather less abundant, is closely allied to *Lepidodendron elegans*, though a comparison of specimens of different sizes induces me to believe it distinct. It is distinguished by elongated ovate areoles, having small triangular leaf-scars. The adjacent areoles are usually separated by a space of regularly corrugated bark, equal to their own transverse diameters. The principal wrinkles are longitudinal; but there is a delicate transverse series, perceptible only in the best specimens. From this character, which can be observed even when the scars are not distinctly preserved, I have provisionally named the species *L. corrugatum*. The decorticated surface of well-preserved specimens of this species presents prominent scars, with the intervening spaces very delicately corrugated transversely.

A third species, still less abundant, has broadly rhomboidal areoles, with rhombic scars, each having three vascular punctures. This species may be *L. Sternbergii*, though I have seen no figure or description of that species giving the minute characters of the scars (see figs. 1, 2, 3, and 1*a*, 2*a*, and 3*a*). It resembles that figured by Dr. Jackson as *L. dilatatum*, from the Albert Mine.

The first and third of these species are found in the middle coal-measures; but I have not seen the second from these: it corresponds in some respects with No. 28 of Mr. Bunbury's List of Plants from Sydney; but I have no specimen or figure of that species for comparison*.

The only other fossil in my collection belonging to this genus is a fragment of a *Lepidostrobus*, showing merely the rhomboidal marks left by the fall of the scales.

All the species aboved noticed are of the slenderly-branched type represented by *L. elegans*.

Along with the *Lepidodendra* are found many stems, which, at first sight, I was disposed to refer to *Knorria* as represented by the *Knorria imbricata* (Sternberg). A careful comparison of a number of specimens has, however, convinced me that they are merely decorticated specimens of *Lepidodendron*, especially *L. elegans*. In many such specimens the areoles are represented by ovate elevations, sometimes presenting an imbricated appearance. *K. imbricata* has been ascertained by Goeppert to resemble *Lepidodendron* in structure; and I suspect that most, if not all, the specimens of the species are imperfectly-preserved stems of *Lepidodendra*. *K. taxina* (L. and H.) is probably distinct generically from these lepidodendroid Knorrias.

2. *Sigillariæ.*—I have but one species of *Sigillaria* from the lower coal-measures. It occurs at Horton, a specimen from which place was presented to me by Professor Stewart, of Acadia College. I have found the same or a similar species at the North River of Onslow, in coal-measures very near the base of the system. Both are ligneous casts, and imperfectly preserved; but in their present state they cannot be distinguished from *S. angusta* of Brongniart, a slenderly-ribbed species, not very dissimilar in its ligneous surface from *S. pachyderma*, which is found in the lower coal-measures in Scotland (Page).

A *Stigmaria* not distinguishable from *S. ficoides* occurs at Horton; and Dr. Harding has a specimen with those peculiar stellate wrinkles which Hugh Miller has remarked on specimens from the Scottish lower coal-measures (*S. stellata*). Cylindrical rootlets, probably of *Stigmaria*, fill some of the beds at Windsor Brook, and may indicate soils in which *Sigillariæ* have grown.

3. *Filices.*—The only Fern hitherto found in the Horton beds was discovered by Professor Stewart. It corresponds with *Sphenopteris adiantoides* of Lindley and Hutton, obtained by them from the Jarrow colliery.

At Moose River, on the north side of Cobequid Bay, in beds which I believe belong to the lower coal-measures, another Fern has been found; it is identical with *Pecopteris Mantellii* (L. and H.). This is the species called *P. heterophyllum* in my 'Acadian Geology.'

A beautiful specimen from Horton presents a dichotomous leaf, with parallel veins, having the general aspect of *Acrostichium* or *Schizea*; I presume it belongs to Brongniart's genus *Schizopteris*.

* Quart. Journ. Geol. Soc. vol. iii.

Its venation is undistinguishable from that of the elongated parallel-veined leaves which I have usually referred to the genus *Poacites*; and I am inclined to suspect that these last, notwithstanding their parallel venation and elongated grass-like forms, are really allied to the Ferns. They were certainly low plants growing in dense clumps in the coal-swamps (figs. 4 and 5).

Fig. 4.—Schizopteris (?), *Lower Coal-measures, Nova Scotia.*
Fig. 5.—Poacites, *Lower Coal-measures, Nova Scotia.*

Fig. 4.

Fig. 5.

*Poacites* are among the most abundant fossils of all the members of the coal-formation; and I cannot find any specific distinction, except such as might be founded on the greater or less slenderness of the leaves. All have parallel veins, raised on one side of the leaf, depressed on the other; and in perfect specimens slender striæ can be detected between these, giving the leaves an aspect akin to those of the family *Typhaceæ*. The veins are pretty constantly one-fiftieth of an inch apart.

An ill-preserved specimen from Horton resembles the genus *Sphæredra* (L. and H.). Similar, though much smaller, specimens are figured by Dr. Jackson as occurring at the Albert Mine.

*Calamites.*—A single ribbed stem from Horton, and another from St. Mary's River, may belong to this genus; but neither were well-characterized specimens.

The above slender list includes all the plants that I have hitherto obtained from the Lower Coal-formation. Multitudes of fragments, destitute of distinct character, are, however, found in these beds; and further observation will no doubt increase the number of species.

### III. *Fauna of the Lower Coal-measures.*

The animal remains found in these rocks correspond in general aspect with those of the middle coal-measures, though I have no doubt that the species are in most cases distinct. They include *Reptilia, Pisces, Entomostraca, Annelida,* and a few *Mollusca,* and are, as far as I am aware, altogether distinct from the fossils of the properly marine members of the system.

*Reptilia.*—Foot-prints of a small quadruped were found at Horton Bluff by Sir W. E. Logan in 1841. Some years later, Dr. Harding, of Windsor, obtained a few series of foot-prints from beds of corresponding age at Parrsboro'. The foot-prints found by Sir W. E. Logan were the first traces of reptilian animals observed in America; but, being imperfect, they did not attract attention until the subsequent discoveries of Dr. King in Pennsylvania, and of Sir C. Lyell and the author in Nova Scotia, had proved the certainty of the indications which these earlier traces afforded. The slab from Horton is now in the Museum of the Canadian Geological Survey. On comparing the impressions with the specimens found by Dr. Harding and myself, I have no doubt that they are Batrachian foot-prints. They appear to have been made, however, by an animal moving under water, and partially supported by the fluid; so that only the points of its toes reached the bottom, except in one place, where an unusual pressure was exerted, perhaps with the view of turning or of stopping suddenly. The creature must have had strong and broadly-pointed claws, by which it urged itself forward. One pair of feet (the hind pair, I presume) had five claws, three of them larger than the others; the other pair of feet may have had only three or perhaps four claws. These appearances would indicate a creature of the type of *Menopoma* or *Menobranchus,* and thus correspond with the inferences deduced by Professors Wyman and Owen from the bones of the *Dendrerpeton Acadianum* of the middle coal-measures. The trail of the tail, seen in the other foot-print referred to, does not appear in the Horton specimen; but this may be due to the support afforded by the water; the others have been probably subaërial.

At Windsor Brook and Parrsboro' I have observed impressions similar to those above referred to, though less distinct and of interest merely as indicating that small Batrachians may have been by no means rare. It is to be hoped that the rich fish-beds of Horton may yet afford some of their osseous remains.

*Pisces.*—Remains of Fishes are extremely abundant at Horton and Albert Mine, but much less so in any other beds of this series that I have examined. At Lower Horton, Halfway River, and Horton Bluff, there are many beds, from a line to three inches in thickness, which may be regarded as consisting of scales, teeth, and bones, mixed with a little siliceous sand, and united by a calcareous cement; and such beds, with still more numerous shale-surfaces covered with similar remains, are seen at intervals through several hundred feet. Enormous quantities of fishes must have perished in this place; and their remains are scattered, as if dispersed by currents after the decay of the animal matter. This, with the great succession of beds containing such remains, indicates the long resort of fishes to the ground, and the accumulation of their remains in the natural course of the death of successive generations. The locality of the fish-remains at Horton is very limited in area, at least to the eastward,—such remains not being found at Windsor, nor at Walton on the opposite side of the estuary of the Avon, though fossil plants occur at these places. This fact and the indentation in the older metamorphic region opposite Horton Bluff, as well as the association of the remains with plants, erect trees, and rippled, shrinkage-cracked, and worm-tracked beds, render it probable that this was an old estuary, acted on by the tides and by river-inundations, and long resorted to by fish, perhaps for the purpose of spawning.

At the Albert Mine the fish-remains are found throughout a great thickness of rock and over a considerable area, since I have found them equally abundant in the continuation of these beds on the east side of the Petitcodiac, above Dorchester. They are usually entire, or at least in groups of scales representing the body of the animal, or a part of it, which appears to have been buried in sediment before decay. In connexion with this difference of preservation, it may be observed that the bituminous shales of the Albert Mine must have been a semifluid impalpable mud, charged with vegetable matter, and likely, when in a state of suspension in water, to prove fatal to fishes. The removal of the free oxygen from water, by the presence in it of large quantities of vegetable matter in a state of putrefaction, is destructive to most fishes, except those furnished, like our modern *Amia* and *Lepidosteus*, with an auxiliary respiratory organ in the form of a rudimentary lung. Most of the fossil Ganoids of the coal-measures must have been similarly provided; else they could not have lived and multiplied in the putrid waters indicated by the beds which contain their remains: but even they may have occasionally been suffocated by unusual quantities of offensive organic sediment. On wide flats also, periodically inundated and dry, large quantities of them, venturing, like the fishes observed by Livingstone in the plains of Loudo, far from the perennial streams, must often have perished.

At the Albert Mine, so far as yet known, all the fishes appear to have belonged to the family *Lepidoidea*, the larger predaceous races being absent. At Horton, on the contrary, though remains of Lepidoids predominate, there were also large fishes of the Sauroid and Cœlacanth families of the Ganoids, and several Placoids.

In the first of these families of Ganoids, the detached scales indicate several species of *Palæoniscus**, which must have been present in great numbers.

Of the Sauroid family, there are teeth, jaws, and scales of a species of *Gyrolepis* or *Acrolepis*, which must have abounded at Horton; and large teeth, having the characters of *Centrodus* (M'Coy).

The Cœlacanth family is represented by large rounded scales, dentary bones, and teeth of a fish belonging, I presume, to the genus *Rhizodus* (Owen), though the cross section of the tooth is nearly round. In the cross section, these teeth present a central cavity, round toward the point, elliptical further down, and surrounded by several layers of radiating dentine, coated externally by a thick layer of enamel. Their bases are deeply plicated.

To the Placoid order belong some fragments of large spines, rarely found in the Horton beds. They appear referable to the genus *Ctenacanthus*.

It is evident, from the presence of the remains of large predaceous fishes, that these frequented the ancient Horton estuary, probably in far greater numbers than the remains now found would indicate. Their voracity may be one cause of the detached state in which the other fish-remains occur; and accordingly many oval patches of scales and teeth are associated with coprolitic matter, in a manner which indicates that they formed the debris of the food of the larger fishes.

Under this head of "Fishes" I am inclined to place certain globular bodies, about a line in diameter, which are very abundantly scattered over the surfaces of some of the beds. They have a thin carbonaceous coating, smooth externally or very finely granulated. They are filled with iron-pyrites or calc-spar; and the manner in which some of them have collapsed, indicates that, when recent, they were tough and membranous. This appearance and their want of resemblance to any known plant of the coal-measures incline me to believe that they are spawn of fishes.

*Entomostraca.*—In a few layers at Horton there are quantities of valves of bivalve Crustaceans of several species. Some of these have ventral furrows like the "Cypridina" of De Koninck; others are ovate and smooth; but none of them appear to be identical with the Cyprids of the middle coal-measures. As the remains of these creatures occur in but few of the fish-beds, I cannot attribute to them any important part in dismembering the remains of the fishes,—an office attributed to them by a recent writer. Specimens of these Crustaceans have been sent to Mr. Rupert Jones, who, I trust, will be able to examine and report on them.

*Annelida.*—Some of the beds of sandstone resting on clay, at Horton and Halfway River, are completely covered with cylindrical casts, apparently of the trails and burrows of worms, causing the

* Dr. Jackson has described several species of the genus *Palæoniscus* from Hillsborough. See 'Report on Albert Mine:' Boston, 1851.

rock to resemble a mass of fossilized maccaroni. Other beds are marked by projections on their under sides, which, I suppose, represent the tracks of worms burrowing in the sand and turning to ascend again on reaching the stiff clay beneath. They are oval prominences, with a deep furrow along the centre, and more delicate furrows extending from this to the margins. They belong to the genus *Nereites*; but it seems unnecessary to give them a specific name. (Figs. 6 and 7.)

Fig. 6.—*Annelide-markings, Lower Coal-measures, Nova Scotia.*

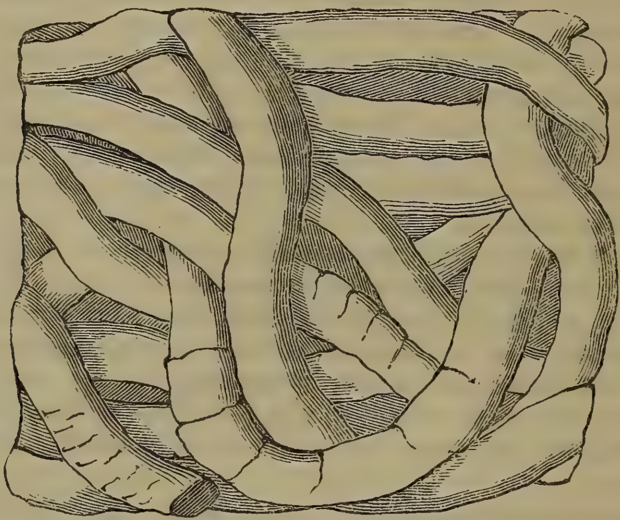
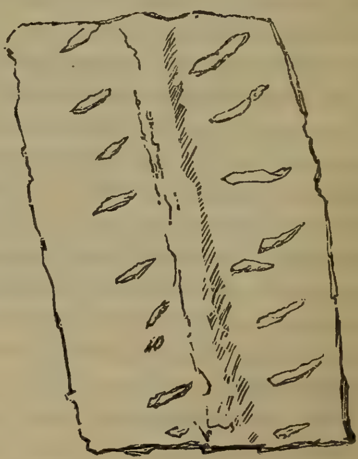


Fig. 7.—*Annelide-markings, Lower Coal-measures, Nova Scotia.*

Fig. 8.—*Track of a Crustacean?, Lower Coal-measures, Nova Scotia.*



Annelid-marks similar to those above noticed occur in various parts of the carboniferous system in Nova Scotia. Five examples from the upper coal-measures were described by the author in

1846*. Those described by Mr. Binney† and by Professor Harkness‡ may have been produced by similar animals, of the same geological age; and the far more ancient impressions from the Longmynds, described by Mr. Salter§, much resemble those delineated in fig. 7. In the Nova Scotia coal-measures these marks appear to be characteristic of the littoral zones (often probably of great extent, owing to the flatness of the bottom) which intervened between the land (or the coal-swamps) and the open waters inhabited by Brachiopods and Corals.

*Mollusca.*—A small Unio-like species from Parrsboro' is the only representative of this province of the animal kingdom, that I have found. It is not distinguishable from species found above the marine limestones; but this peculiar form of bivalve is confined to the plant-bearing beds, and does not occur in the strictly marine parts of the system. It was probably a fresh- or brackish-water shell.

*Markings.*—On the surfaces of the beds at Horton there are many singular markings, different from those which resemble trails of Annelids. Most of them are mere scratches, perhaps of drift wood, or of fins of fishes. One of the most curious forms is a furrow, having on each side a series of transverse markings, which may have been caused by the feet of Crustaceans (fig. 8). At the termination of such tracks there is usually a brush of curved scratches, inclined to one side, as if the creature had raised itself from the bottom to swim off.

These markings, and the numerous smooth and distinct strata-surfaces at Horton, show that the process of deposition was slow and interrupted; and it is probable that many of these surfaces, especially those covered with fish-scales, long formed the bottom of clear water tenanted by fishes. On the other hand, occasional beds of coarse sandstone and thick imperfectly-bedded shales, and the presence of beds with erect trees, indicate occasional deposition of large quantities of sediment and important changes of level. In these respects the lower coal-measures resemble those higher in the system: but the presence of subaquatic conditions was greater in the former; and while, on the one hand, the oceanic conditions of the marine limestones with Brachiopods and Corals are absent, on the other hand the terrestrial surfaces of the middle coal-period are rare. The peculiar character of these beds, in reference to the life of the period, is that they afford the first traces of its plants and shore-animals, and that they show us the inhabitants of swampy estuaries and forest-clad river-valleys mingled with the remains of fishes that may have occasionally visited the surf-washed coral-reefs of the distant sea.

The lower coal-measures contain no valuable beds of coal. Their sandstones are sometimes quarried for building-purposes; and their

* Quart. Journ. Geol. Soc. vol. ii. p. 132.
† Trans. Lit. Scien. Soc. Manchester, vol. x.
‡ Edinb. New Phil. Journ. new series, vol. i.
§ Quart. Journ. Geol. Soc. vol. xiii. p. 199.

laminated calcareous shales, rich in the phosphate of lime of fish-remains, might be used for agricultural purposes. The highly bituminous shales of Albert have been used for the manufacture of hydrocarbons. The singular and anomalous bed or vein of highly bituminous coaly matter at Albert is the most valuable deposit hitherto found in this series.

The absence of large beds of coal corresponds with the rarity of terrestrial surfaces, and of remains of Sigillarioid and Coniferous trees, the growth and accumulation of which, and of the rank undergrowth of *Calamites*, *Poacites*, and Ferns, seem to have characterized the coal-swamps of the middle coal-measures.

The observations of Sir W. E. Logan on Stigmarian underclays, in connexion with the subsequent discovery that the *Stigmariæ* are roots of *Sigillaria*, have established the connexion of these plants with the production of coal; and as long ago as 1845* I had convinced myself, by microscopic investigation of the coal of the main seam of Pictou, that this very thick bed consists, in great part, of the wood of Sigillarioid and Coniferous trees, which last are proved, by the Joggins section, to have actually grown in the coal-swamps. Regarding these as undoubted truths, I have been surprised to find so much uncertainty on this subject expressed by late writers, and have, in consequence, entered on a careful re-examination of the Pictou, Sydney, and Joggins coals of the Middle Coal-measures, with the aid of specimens collected during many years with this object, and prepared by chemical methods, which, in some instances, enable me to reproduce the organic tissue in all its original perfection. I am not yet prepared to state all the results of this inquiry, but may give the following as ascertained facts, bearing on the statements above made respecting the flora of the Lower Coal-measures.

1. By far the greater part of the tissues retaining structure are Sigillarioid or Coniferous.

2. The perforated tissue of the "mineral charcoal" is merely an altered condition of scalariform and disc-bearing vessels and cells.

3. The differences in the laminæ of coarse, bright, and fibrous coal depend less on difference of material than on the amount of decay the vegetable matter suffered before being finally excluded from atmospheric influence.

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## 4. *Some Observations on* Stigmaria ficoides.

By E. W. Binney, Esq., F.R.S., F.G.S.

[Plate IV.]

During the past year it has been my good fortune to meet with several specimens of this singular root, which throw some additional light on the origin of its medullary rays,—the nature of the vascular bundles which were believed to be dispersed throughout its pith,—and the structure of the central or vascular portion of its rootlet;

* Quart. Journ. Geol. Soc. vol. ii. p. 134.

points of considerable interest, and which up to the present time have not been well determined.

First, as to the origin of the medullary ray, and the nature of the vascular bundles in the pith—Dr. Joseph Dalton Hooker, in summing up the state of our knowledge of *Stigmaria**, in 1848, describes the woody axis of the root, and figures two characteristic specimens, one showing the large medullary rays or bundles, and the other the narrow rays. The author then says: "the medullary rays, even the narrowest, are traversed by bundles of tubes, half the diameter of the largest vessels of the axis (or wood), or even less (pl. 2. figs. 6, 7*a*, and 8). The transverse lines on their surface are generally finer and less crowded. These bundles evidently originate in the cellular axis of the stem, and do not belong to the wedges of vascular tissue (or wood) between which they run, as they appear to have done in M. Brongniart's† specimen of the plant, both from his figure and description. I cannot, however, but conclude the latter to be erroneous, because M. Goeppert, whose specimens appear to have been in this respect more perfect than any hitherto illustrated, represents the bundle of vessels which proceed from the axis, run between the wedges of wood, and communicate with the rootlets (leaves, Goepp.), as originating in isolated bundles irregularly scattered in the medullary axis of the stem. Of the existence of these bundles there are some indications in my own specimens, though for the most part they have been destroyed by the cellular tissue of the plant, which indeed often takes place with the system of vessels from which the leaves, rootlets, or scales of the cones in the fossils are supplied. It is so in the stems of *Lepidodendron*, in the axis of *Lepidostrobi*, in the portion of the *Sigillariæ* figured by M. Brongniart, and in other fossils contained in the Museum of the Survey, and is probably owing to their great delicacy, for they are much more membranous in appearance than the similarly-marked vessels of the wood.

The most important circumstance thus developed is the existence of a double system of vessels in *Stigmaria*, first shown by Goeppert, and the consequent approach, in this respect, to *Diploxylon*‡, Corda. In *Diploxylon*, however, the inner system forms a continuous cylinder, concentric with and in juxtaposition to the wedges of wood forming the outer; whilst in *Stigmaria* the same inner system is broken up into scattered bundles, apparently unsymmetrically arranged in the medullary axis or pith of the plant.

1. Now, as to the medullary rays of *Stigmaria* coming direct from the axis of the stem, and not originating in the vascular cylinder. as supposed by M. Brongniart, a specimen in my cabinet (Pl. IV. fig. 18) shows this most decisively, and fully confirms Dr. Hooker's views as hereinbefore quoted. In this specimen the woody cylinder

* "On some peculiarities in the structure of *Stigmaria*," by Dr. Hooker, F.R.S., and Botanist to the Geological Survey of the United Kingdom; Memoirs of the Geological Survey, vol. ii. Part 2. p. 434.

† Archives du Muséum d'Hist. Nat. vol. i. p. 405, t. 29. f. 3 *d*.

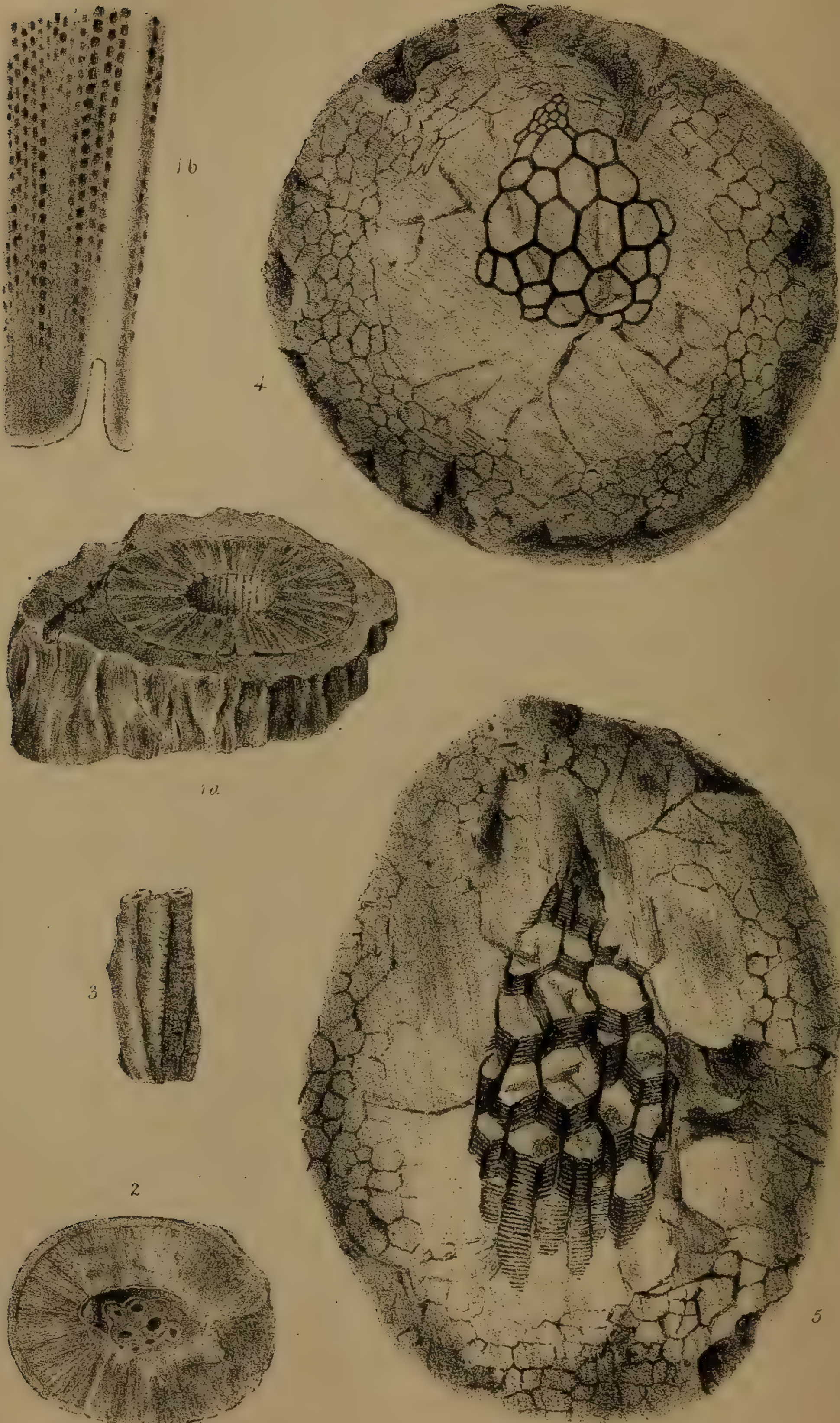
‡ Corda, Flora der Vorwelt, p. 34, pl. xi.

is rather more than an inch in diameter and quite uncompressed; and, owing to the axis of the stem having slipped out of the specimen, the perforations in the narrow ends of the wedge-shaped bundles of wood through which the medullary rays passed are most distinctly shown. They are long and narrow, and occur in an irregular quincuncial order, as shown in my figure above named.

2. As to the supposed vascular bundles dispersed throughout the pith. Plate IV. fig. 2. represents a transverse section (natural size) of the woody cylinder of *Stigmaria*, lately found by me in the middle of a seam of coal in North Staffordshire. The specimen is highly charged with iron pyrites, but it shows the characteristic reticulated structure and medullary rays beautifully. The axis is filled with eleven or twelve large vessels of a circular or oval form, each of about one-tenth of an inch in diameter, having very thick walls*. These vessels appear not to have been dispersed throughout the cellular tissue, but lying contiguous to each other, whilst a small space is left near the edge of the woody cylinder, as if resulting from shrinkage. Their large size is very remarkable, far exceeding anything of the kind that has come to my knowledge in fossil-plants. Fig. 3 presents a longitudinal view, natural size, of these vessels, and shows them to be elongated utricles; and, although much larger in size, of similar shape to those described by M. Brongniart as occurring in the woody part of *Sigillaria elegans*. The pyritized condition of the walls does not enable me to decide that these vessels are marked by transverse striæ on their different sides, but they certainly have something like an appearance of that kind in the arrangement of the pyrites. No traces of the insertion of medullary rays or bundles could be detected on the sides of the vessels. Altogether these singular vessels remind me somewhat of the vascular tissue in the middle of *Anabathra*, and of an undescribed plant (in my cabinet) allied to the genus *Lepidodendron*, except that the vessels are much larger, and their walls much thicker.

3. As to the structure of the rootlets of *Stigmaria*. In the Memoir previously quoted, Dr. Hooker, at page 533, describes a specimen of a rootlet showing structure. He says,—"For the highly interesting specimen of a rootlet in which the cellular tissue is preserved, the Museum is indebted to Mr. Warington Smyth (Mining Geologist to the Geological Survey). It is figured at pl. 2. fig. 1, and consists of the silicified lower portion of a rootlet, the sides of which have collapsed, so as to reduce its originally cylindrical form to that of an irregularly four-sided prism. The substance is formed of a network of exceedingly delicate cellular tissue (pl. 2. figs. 2 and 3), composed of hexagonal cells; and it is traversed throughout its length by a dark line (fig. 2*a*), no doubt indicating the prolongation of one of those slender bundles of vascular tissue which issue from the medullary rays of the axis (*a* of figs. 6 and 7), and thence proceed to the mamillæ on the surface of the specimen,

* Some to whom this specimen has been shown regard these tubes as being due to the mineralized condition of the central portion of the axis; but I certainly consider them to be the representatives of the vascular tissue.




G. West del. et lith. ad nat.

W. West imp.

STIGMARIA

figured at fig. 4, or the bases of the cavities in the figures in plate 1. This very simple structure of rootlet is similar to that of several *Lycopodia*, and indeed of many other plants, both Monocotyledonous and Dicotyledonous, so far as can be ascertained without a further knowledge of the axis of the organ; of the structure of which, however, there can exist no reasonable doubt, since it may be confidently assumed to consist of a bundle of vessels, similar to those represented at fig. 7*a*."

The specimen of the rootlet of *Stigmaria* now about to be described, was found by me during the last summer on an old coal-pit hill at Over Darwen, Lancashire; it occurred in a nodule of clay-ironstone, most probably derived from the roof of one of the lower seams of that district. The rootlet from which my sections have been made was from a part about half an inch from the root; it is quite cylindrical, and was originally one-fourth of an inch in diameter, but since its fossilization it has diminished one-half, probably owing to the removal of its thick carbonaceous exterior. The remaining eighth of an inch is for the most part composed of crystallized mineral matter (silica most probable); and it is only a small circular speck, of about one-thirtieth of an inch in diameter, in the centre of the rootlet, that affords structure. With the assistance of Mr. Cuttell, I have been able to obtain a good transverse, and a moderately fair longitudinal, section of this small specimen.

First as to the transverse section. Its exterior consists of a ring of very fine cellular tissue three or four cells broad. This is succeeded by a space, about five times the diameter of the ring above named, in which no structure is apparent; the fine tissue having disappeared: then in the centre is a beautiful pear-shaped mass of vascular tissue, one-ninetieth of an inch diameter, consisting of 27 large vessels, having hexagonal, pentagonal, and other openings, and of a bundle of 11 very minute nearly circular vessels at one extremity, as shown in Plate IV. fig. 4, in the transverse section.

The longitudinal section, Plate IV. fig. 5, is not true, being about half-way between a transverse and a longitudinal section; but it clearly shows that the vascular utricles or vessels were marked with transverse striæ on their different sides, and, although of such minute dimensions, corresponded with the vessels found by M. Brongniart in *Sigillaria elegans*, and similar to what Dr. Hooker supposed they would be, although probably considerably smaller in size.

The appearance of the vessels in their transverse section, both the large and small ones, remind me of the section of a root of *Aspidium exaltatum* figured by M. Brongniart, in plate 8 (xxxii.), fig. 10 of that learned author's "Observations sur le *Sigillaria elegans*," except that the vascular bundle of my specimen is somewhat pear-shaped, and not irregular stellate, as in the transverse section of *Aspidium*.

## EXPLANATION OF PLATE IV.

Fig. 1, *a*. A portion of the woody cylinder of *Stigmaria ficoides*, presenting a transverse section, and showing the orifices through which the medullary rays or bundles passed from the centre of the root to the exterior. Natural size.

Fig. 1, *b*. A portion of a medullary ray, from the same specimen. Magnified ten diameters.
Fig. 2. Transverse section of the woody cylinder and centre of *Stigmaria ficoides*, showing the large vessels (?) or utricles in the axis. Natural size.
Fig. 3. Longitudinal view of the large vessels (?) or utricles in the axis of *Stigmaria ficoides*. Natural size.
Fig. 4. Transverse section of the centre of a rootlet of *Stigmaria ficoides*, showing the ring of cellular tissue and the vascular bundle in the middle. Magnified ninety diameters.
Fig. 5. Section, partly transverse and partly longitudinal, showing the ring of cellular tissue and the transversely rayed vessels or utricles of the vascular bundles. Magnified ninety diameters.

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## 5. *On a Species of* Fern *from the* Coal-Measures *of* Worcestershire. By John Morris, F.G.S.

Ferns with reticulate venation are comparatively rare in the Coal-measures, at least in this country, where no species having that character has, I believe, been hitherto recorded. Two or three pieces of micaceous sandstone, recently obtained by Mr. G. Roberts of Kidderminster, contain portions of fronds showing distinctly a loose reticulation or anastomosing venation. They were obtained by him from a shaly sandstone of the Coal-measures near Bewdley, and are associated with *Pecopteris Serlii*, *P. lonchitica*, *P. oreopteridis*, a form allied to *Sphenopteris latifolia*, *Lycopodites*, and *Nœggerathia* (?).

The genera which have been established for the reception of those fossil forms of the Coal-measures, having a more or less reticulate or anastomosing venation*, are *Lonchopteris*, *Woodwardites*, and *Dictyopteris*.

### Lonchopteris, Brongniart, 1827.

Frond bipinnate or many times pinnatifid; pinnulæ more or less adherent at their base, traversed by a midrib; secondary veins reticulate.

This genus has the general form of *Pecopteris*, but is readily distinguished from it by the regular reticulated arrangement of the secondary veins. Five species are recorded, three belonging to the Coal-measures—*L. Bricei* (Brongn.), *L. rugosa* (Brongn.), and *L. anomala* (Göpp.) from the coal-schist of Zwickau; the other two species have been found in the Oolitic (*L. Huttonii*) and Wealden (*L. Mantelli*) strata of England: the latter also occurs in the lower greensand of the Isle of Wight. Another species has recently been added to this genus,—the *L. Germari*, Giebel (Zeitschrift für die gesammten Naturwissenschaften, 1857, vol. x. p. 301, pl. 1), from the coal

* The *Pecopteris Defrancii*, Brongn. (Hist. Vég. Foss. p. 325), has the secondary veins sometimes anastomosed (pl. 112. f. 1). This species is considered by Brongniart to be the type of the section *Neuropteroides* of the genus *Pecopteris*. The *Neuropteris conferta*, Sternb., has a lax venation, the secondary veins occasionally presenting the appearance of anastomosing. (Göppert, 'Die Gattungen der fossilen Pflanzen,' Lief. 5 und 6. t. 10. f. 2, 3.)

of Löbejün. This species has the general habit of *Neuropteris*; the pinnulæ appear to bef ree, the midrib is distinct, and the venation reticulate.

### WOODWARDITES, Goeppert, 1836.

Frond pinnatifid; midrib distinct; veins areolate; reticulate, dichotomous towards the margins; areolæ irregular, those near the midrib larger in proportion. Pinnulæ strongly decurrent to the rachis.

This genus, established by Goeppert for two fossil ferns (*W. obtusiloba* and *W. acutiloba*) from Waldenburg, Silesia, is closely allied to, and difficult to separate from, *Lonchopteris*; the second species (*W. acutiloba*) presents, in its regular reticulate venation, an analogy to *Lonchopteris Bricei*, Brongn. pl. 131. f. 2, 3, and differs from the *W. obtusiloba*, which, according to Brongniart, should not be placed in this genus. Brongniart* has, however, arranged two other species under *Woodwardites*,—the *W. Muensterianus*, Sternb. sp. (Flor. der Vorwelt, ii. t. 36. f. 2), and the *W. Rœmerianus*, Unger (Chlor. Protog. t. 37. f. 4), the latter from the Tertiary strata, and resembling the recent *Woodwardia radicans*.

The genera *Lonchopteris* and *Woodwardites* have been considered by Brongniart and Goeppert to be allied to *Lonchitis* and *Woodwardia*; they differ, however, in not having the regular areolæ, parallel to the midrib, which exist in those recent genera, more especially in the latter.

### DICTYOPTERIS, Gutbier, 1835. (*Linopteris*, Presl.)

Frond pinnate or pinnatifid?; pinnulæ oblong, straight, sessile; veins reticulate; areolæ hexagonal, elongate in the centre, and somewhat parallel to the margins of the pinnulæ, afterwards oblique and then free near the margin; no midrib.

This remarkable genus was established by Gutbier for those fossil ferns possessing the general habit of *Neuropteris*, but differing from it in having a somewhat radiate reticulate venation and *no distinct midrib*, in which latter character it differs from both *Lonchopteris* and *Woodwardites*. Four species are described,—the type, *Dictyopteris Brongniartii*, Gutbier (Verst. der Zwickauer Schwartz-Kohle, p. 63, pl. 2. f. 7, 9, 10), from the coal-schists of Saxony; *D. Muensteri*, Eichwald, sp., very frequent in the coal-measures of Southern Russia; *D. obliqua*, Bunbury (Quart. Journ. Geol. Soc. iii. p. 427), from the coal-measures of Nova Scotia; and M. Brongniart mentions a fourth species from the eastern part of Egypt†.

Presl subsequently established a recent genus, *Dictyopteris*‡, for certain species of *Polypodium* having a reticulate venation and no free veins, as *P. attenuatum*, Brown, and changed the name of the fossil genus to *Linopteris*; but the right of priority appears to

* Tableau des genres des Végétaux Fossiles, 1849. † Ibid.
‡ Tentamen Pteridographiæ, 1836.

belong to Gutbier. Mr. J. Smith*, whose valuable researches and works on the recent ferns are well known, has substituted the name *Dictymia* for the living ferns assigned to *Dictyopteris* by Presl.

### Woodwardites? Robertsi, sp. nov.

The specimen figured (figs. 1, 2) is unfortunately only a portion of a frond, so that the character of the fern cannot be fully described. It probably represents the terminal part of a pinna, and consists of five more or less alternately opposed pinnules, which are ovate and obtusely pointed, with entire margins, and broadly adherent at their base: there is no midrib; the venation is anastomosing; the areolæ are large and irregularly hexagonal, some elongate and parallel in the middle of the pinnules, afterwards oblique and then free near the margins; there are no free veins within the areolæ: in this latter character it is similar to the genera above mentioned; and this feature is also found in some recent ferns, as in *Litobrochia* (*L. pedata*) and other genera.

Figs. 1 & 2.—Woodwardites? Robertsi, *from the Coal-measures near Bewdley, Gloucestershire.*

Fig. 1.—*Portion of the Frond.*

Fig. 2.—*Leaflet, magnified.*

In the reticulate venation and the absence of a distinct midrib, this fern is allied to *Dictyopteris*; but in the general habit, mode of venation, and broad decurrent base of the pinnules, it more closely resembles those ferns referred by Goeppert to his genus *Woodwardites* (near to *Lonchopteris*, Brongn.), and, with the exception of

* Enum. Filic. Hort. Kew. 1846. See also his useful Catalogue of Cultivated Ferns, with generic descriptions: London, 1857.

not possessing a distinct midrib, it appears allied to the species described by him under the name of *W. obtusilobus** from the coal-measures of Waldenburg in Silesia.

In describing these fragments, I have merely wished to call the attention of collectors, and those resident near our coal-fields and interested in the palæozoic flora, to this comparatively scarce fern, in the hope of obtaining some further information on the subject, or the loan of specimens which would more completely indicate its true affinities.

For the present I would provisionally assign it to the genus *Woodwardites*, with the specific name of *Robertsi*, in honour of the discoverer.

It may, however, hereafter prove to be merely some abnormal condition of a species of *Sphenopteris*, *Pecopteris*, or *Neuropteris* (like *N. conferta*, Sternb.).

*Locality.* Collected from a thin bed of light-coloured micaceous sandy shale, occurring between two beds of coarse grit, and considered by Mr. Roberts to belong to an estuarine deposit of the coal-period. These beds lie unconformably on Old Red Cornstone, just below the Hill Farm, on the east bank of the Severn, about two miles north-east of Bewdley.

*Table of the Chief Forms of the* FOSSIL FERNS *which have a* RETICULATE *or* ANASTOMOSING VENATION.

| | | |
|---|---|---|
| Andriania Baruthina | *Braun* | Lias. |
| Camptopteris Bergeri | *Sternberg* | Lias. |
| ,, crenata | *Sternb.* | Lias. |
| ,, biloba | *Sternb.* | Cretaceous. |
| ,, Muensteriana | *Sternb.* | Lias. |
| Clathropteris meniscioides | *Brongniart* | Trias. |
| ,, Nilssoni | *Brong.* sp. | Oolite? |
| Dictyophyllum ? rugosum | *Lindl. & Hutton* | Trias. |
| Dictyopteris Brongniarti | *Gutbier* | Coal-measures. |
| ,, neuropteroides | *Gutbier* | Coal-measures. |
| ,, obliqua | *Bunbury* | Coal-measures. |
| ,, spec. nov. | *Morris* | Jurassic ?, India. |
| Diplodictyum obtusilobum | *Braun* | Lias. |
| Glossopteris Browniana | *Brongn.* | Coal-measures. |
| ,, angustifolia | *Brongn.* | Coal-measures. |
| ,, Phillipsii | *Brongn.*(pars) | Oolite. |
| Gutbieria, *Presl*; referred to *Cyatheites* and *Pecopteris* by Goeppert. | | |
| Lonchopteris Bricei | *Brongn.* | Coal-measures. |
| ,, anomala | *Brongn.* | Coal-measures. |
| ,, Germari | *Giebel* | Coal of Löbejün. |
| ,, ? Huttoni | *Presl* | Oolite. |

* Syst. Fil. Foss. p. 289, tab. 21. f. 1; Nova Acta Acad. C. L.-C. Naturæ Curiosorum, vol. xvii. Supp. 1836.

| | | |
|---|---|---|
| Lonchopteris Mantelli | *Brongn.* | Wealden and Lower Greensand. |
| ,, rugosa | *Brongn.* | ? |
| Phlebopteris contigua | *Lindl. & Hutton.* | Oolite. |
| Sagenopteris cuneata | *Lindl. & Hutton.* | Oolite. |
| ,, Phillipsii | *Sternb.* | Oolite. |
| Thaumatopteris Muensteri | *Goepp.* | Lias. |
| Woodwardites acutilobus | *Goepp.* | Coal-measures. |
| ,, Muensterianus | *Braun* | Brown-coal. |
| ,, obtusilobus | *Gœpp.* | Coal-measures. |
| ,, ? Robertsi | *Morris* | Coal-measures. |

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## May 12, 1858.

Walter Jauncey, Esq., Birmingham, and Edmund Cavell, Esq., Saxmundham, were elected Fellows.

The following communications were read:—

1. *On some of the* Glacial Phenomena *of* Canada *and of the* North-eastern Provinces *of the* United States *during the* Drift-Period. By Professor A. C. Ramsay, F.R.S., F.G.S.

[The publication of this Paper is unavoidably deferred.]

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2. *On* Lamination *and* Cleavage *occasioned by the* Mutual Friction *of the* Particles *of* Rocks *while in* Irregular Motion. By G. Poulett Scrope, Esq., M.P., F.R.S., F.G.S.

(This paper was withdrawn by the permission of the Council.)

[Abstract.]

The author referred to a former paper read by him before the Society in April 1856, in which this subject was touched upon, and proposed to carry on the inquiry as to the probable effect, upon the internal structure of rocks, of the mutual friction of their component parts, when forced into motion under extreme and irregular pressures. He commenced by examining the laws that determine the internal motions of substances possessing a more or less imperfect liquidity, whether homogeneous, or consisting of solid particles suspended in, mixed with, or lubricated by any liquid, under unequal pressures; and showed that unequal rates of motion must result in the different parts of the substance, and that in the latter case there will be more or less separation of the solid and coarser from the finer and liquid particles into different zones or layers, those composed of the former moving less readily than those composed of the latter; and also that the former will, by the friction attending this process, be turned round so as to bring their major axes in the line of direction of the movements, and, if susceptible of tension or disintegration, will be elongated or drawn out in the same direction.

In illustration of this law, specimens of marbled paper were produced, being impressions from superficial films of coloured matter floating upon water in circular or irregular forms after they had been subjected to motion in one or more directions by lateral pressure,—the appearances produced bearing a very exact resemblance to those presented by the lamination and occasionally sinuous or contorted structure of the ribboned lavas of Ponza, Ischia, the Ascension Isles, &c., as well as that of gneiss and mica-schist.

The author proceeded to state that the expansion of a subterranean mass of granite by increase of temperature, to which all geologists agree in ascribing the elevation of overlying rocks, must be accompanied by great internal movements and consequent mutual friction among the component parts, and even among the individual crystals; that, if a lubricating ingredient, such as water holding silex in solution, or gelatinous silex, be intimately mixed up with the more solid crystals (as there is great reason to believe to have been the case in granite), the friction will be lessened, especially in the central or inferior parts of the mass, where the expanding movement, or intumescence, may be supposed nearly uniform in all directions. But in the lateral and higher portions directly exposed to the resistance and pressure of the overlying rocks, shouldered off on either side by the expanding granitic axis, the movement will probably have been so predominant and extreme in a direction at right angles, or nearly so, to the pressure, as to give rise to a lamellar arrangement of the solid crystals, in the manner before indicated. In this manner he supposed the foliation or lamination of gneiss and mica-schist to have been produced through the "squeeze and jam" of the lateral and superficial portions of a granitic mass expanding by increase of temperature, and the giving way of the overlying rocks, those portions being forced to move in the direction of the lamination while subject to intense pressure at right angles, or nearly so, to that direction. The author argued that it is not inconsistent with this view, to suppose that a certain amount of recrystallization may have accompanied or followed this lamellar arrangement; in which case also the major axes of the crystals would be likely to take a direction perpendicular to the pressure, since the mobility necessary to the crystallific action will have been freer in that than in any other direction. He likewise pointed out that the influence of internal friction accompanying motion under extreme and irregular pressures must have been equally operative in the case of aqueous as of igneous rocks, under similar circumstances of imperfect liquidity, and irrespective of changes of temperature. And he suggested that to this cause may be attributable the internal structure of some veined marbles, calcareous breccias, serpentines, &c., as well as the cleavage of the slaty rocks,—as, indeed, the experiments of Mr. Sorby and of Professor Tyndall have already indicated. He concluded by suggesting to all geologists engaged in the examination of rocks the above mechanical considerations, as likely to lead to more definite views than at present prevail as to the origin of the metamorphic schists, and the internal structure of many of the older and more disturbed rocks of all characters.

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### May 26, 1858.

Henry Duckworth, Esq., Liverpool, David C. Macconnel, Esq., Tooting Common, John Entwisle, Esq., Russell Square, and Frederick Drew, Esq., Geological Survey of Great Britain, were elected Fellows.

The following communications were read:—

1. *On the* Pleistocene Sea-bed *of the* Sussex Coast, *being the Western Extension of the* Raised Sea-beach of Brighton. By Joseph Prestwich, F.R.S., Treas. Geol. Soc.

[The publication of this Paper is unavoidably deferred.]

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2. *On the Sedimentary and other External Relations of the* Palæozoic Fossils of the State of New York. By J. J. Bigsby, M.D., V.P.G.S.

[The publication of this Paper is unavoidably deferred.]

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### June 9, 1858.

Major Edward Robert Wood, Stout Hall, Glamorganshire; Charles Falconer, Esq., Sackville Street; William S. Clark, Esq., Mining Engineer, Aberdeen, Glamorganshire; Thomas Evans, Esq., Government Inspector of Coal Mines, Cardiff; William Henry Le Fevre, Esq., Jersey; and John Millar, Esq., Bethnal House, Bethnal Green, were elected Fellows.

The following communications were read:—

1. *On the* Jointings *in the* Carboniferous *and* Devonian Rocks *in the District around* Cork; *and on the* Dolomites *of the same District.* By Prof. Robert Harkness, F.R.S., F.G.S.

Contents.

On the Joints.

*Jointings in the "Brownstone" and "Yellow Sandstone."*—The country around Cork is well marked by peculiar features, which have resulted from the nature of the sedimentary rock occupying this area, and from certain physical changes which have operated on these rocks subsequent to their deposition.

The contour of the district exhibits a series of low hills generally ranging in nearly an east and west direction; and these hills are composed of Devonian sandstone. Separating the east and west ranges of hills are valleys; and in many of them Carboniferous limestones are seen, and other rocks appertaining to the lower portion of this formation,—the areas of Carboniferous rocks being the remains of much larger masses which have been removed by denudation.

The physical features of this district have originated from a succession of rolls, which have affected the strata after the deposition of the Carboniferous series.

In the deposits which here form both the Devonian and the Carboniferous formations there are seen well-developed series of jointings; these, however, are more extensive, and occur in greater variety, in the limestones of the Carboniferous group. In the Devonian rocks (which consist of fine-grained dark-coloured sandstones, well marked by cleavage, and locally called "brownstones" in the lower portion which is here developed, and light-coloured sandstones, the "yellow sandstones" of the Irish geologists, in their higher parts) the jointings in general only manifest one direction, which is nearly N. and S.; and these N. and S. joints are, for the most part, vertical, and in some instances approximate to each other. The joints pervade both the "brownstone" and the "yellow sandstone," but, on the whole, are better developed in the former. They make their appearance wherever the solid rock occurs, and are seen affecting the "yellow sandstones" (which here have greenish strata associated with them) and the higher members of the "brownstones" at Ballefouloo, about a mile west from Monkstown (fig. 1). These N. and S. joints, if we adopt the nomenclature of Prof. Sedgwick, are to be regarded as "*dip-joints*," or, in the language of Prof. Phillips, may be termed "*master-joints*."

An excellent section, showing the "brownstones" and "yellow sandstones," occurs on the road by the sea-margin between Passage and Monkstown. Here we have the physical features of these deposits, in the form of cleavage and jointing, well manifested; and there is one feature, of a negative character, as seen in this section, worthy of remark, namely, the absence of any trace of *strike-joints* where, from the nature of the section, had they occurred, they must have been very apparent.

Abundance of divisional planes, having an east and west strike in the form of cleavage, occur; and the presence of them may have

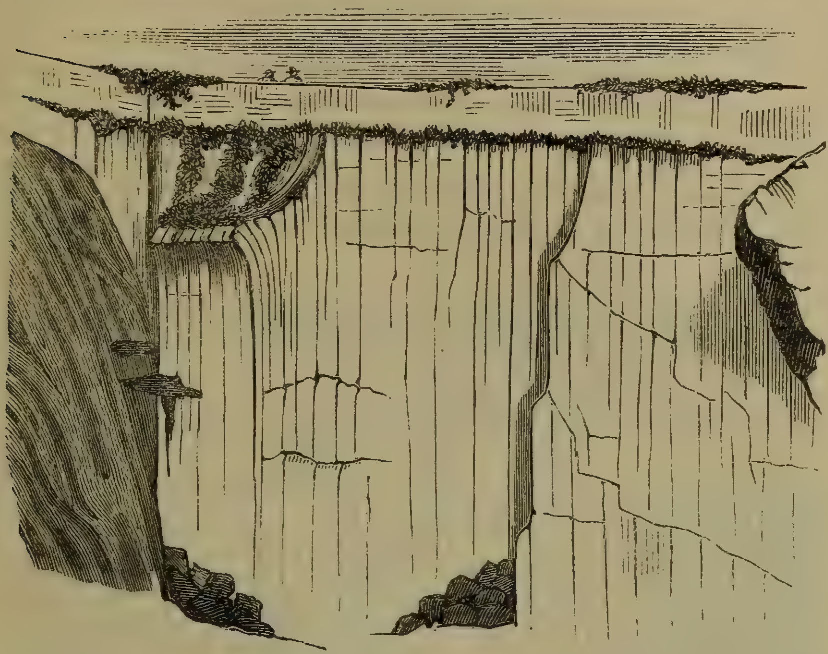
Fig. 1.—*Joints (N. and S.) in the "Yellow Sandstone" and the upper members of the "Brownstones," at Ballefouloo, near Monkstown, Co. Cork.*

some influence on the absence of strike-joints among the Devonian rocks in this locality.

*Jointings in the Carboniferous Limestone.*—It is in the Carboniferous formation, more particularly in the limestone portion, that we have the features of jointing exhibited in their most perfect form. North and south joints are even better developed in most of the limestones than in the members of the Devonian series; and frequently these are seen so arranged that they appear cutting the limestones in such a manner as to give them the aspect of vertical strata, of not more than six inches in thickness each, so closely are they approximated. This course of jointing, although the most prevalent, is not the exclusive form in these limestones. It is well seen in the quarry at Ballintemple, on the south face; but here it does not cut up the limestones into such thin masses (fig. 2); and in this quarry traces of the original stratification can be seen, here striking E. and W., and almost vertical, but with slight contortions. In general, it is only in such limestones as manifest merely the N. and S. joints that any information can be found as to the arrangement of the original bedding.

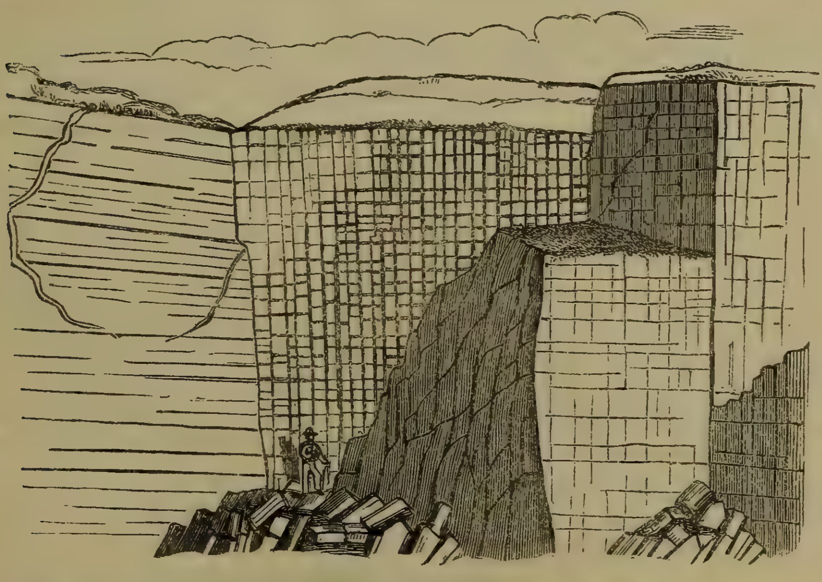
Besides the N. and S. jointings the limestones exhibit others, which, although not so permanent, are in many instances well developed. One of these is almost horizontal, but sometimes manifests a slight south dip; and this course of jointing is known to the workmen in the several quarries under the name of "bedding." It is well seen

Fig. 2.—*Joints (N. and S.) in the Carboniferous Limestone at Ballintemple, Co. Cork.*



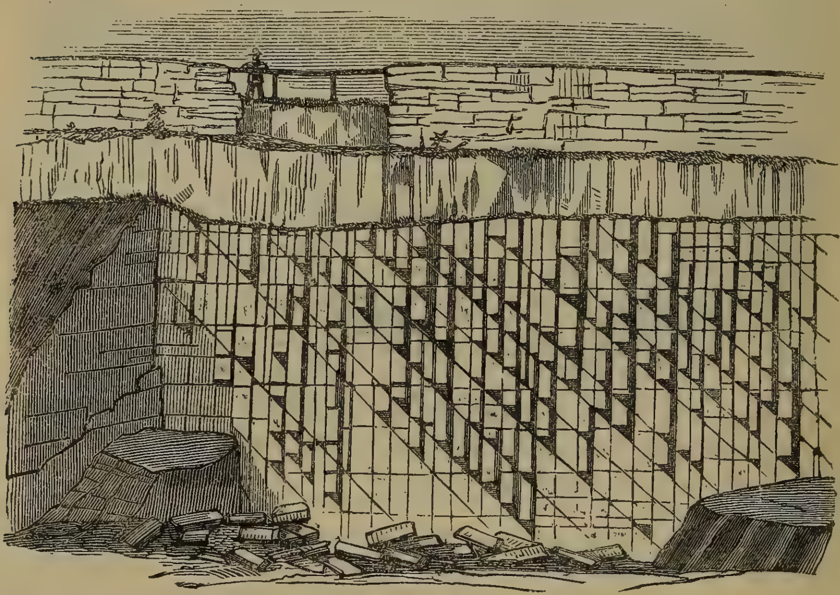
in the quarry at Little Island (fig. 3): and here, where it intersects the perpendicular N. and S. joints at nearly right angles, it gives to the face of the rock a prismatic aspect.

Fig. 3.—*Joints (horizontal) in the Carboniferous Limestone at Little Island, Co. Cork.* Looking North.



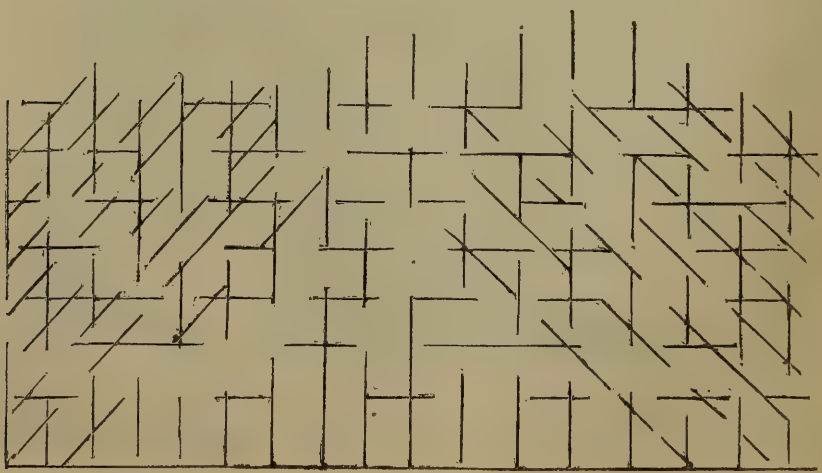
Another course which jointing assumes among these limestones is in a form which, to some extent, may be regarded as somewhat of the character of strike-joints; but this description of joints has only very partial representatives in the joints immediately referred to. These joints are generally inclined at a considerable angle, usually approximating 45°: in some instances dipping west, and in others east. These inclined joints are generally secondary to the other two forms; and, where they make their appearance, are in all instances accompanied by the N. and S. joints, and commonly also by

Fig. 4.—*Joints (N. and S., horizontal, and inclined) in the Carboniferous Limestone at Ballinure, near Black Rock, Co. Cork.* Looking South.



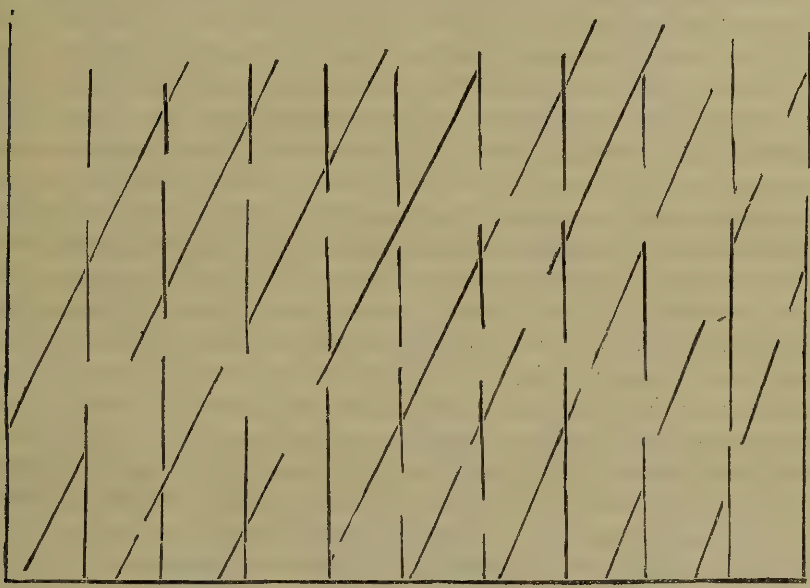
the horizontal joints previously alluded to. They are, however, less common than the other two descriptions. The whole three series are well seen in the quarry at Ballinure near Black-Rock (fig. 4),

Fig. 5.—*Joints (three courses) in the Carboniferous Limestone on the north face of Glasheen Quarry, near Cork.*



and in the old quarry at Glasheen, about a mile west from Cork. The whole series is also represented on the north face of this quarry (fig. 5); and here we have the inclined joints on the west side dipping west, and on the east side, east at nearly the same angle. The features of jointing, as exhibited at this quarry, are shown in fig 5. There are instances where oblique joints have not the usual east and west inclination, and where they are not accompanied by horizontal joints, or at least only very partially so. An instance of this kind occurs in the north end of the principal cutting of the Cork and Passage Railway (fig. 6), where N. and S. joints are seen devoid of

Fig. 6.—*Joints (two courses) in the Carboniferous Limestone at the north end of the cutting in the Cork and Passage Railway.*



those of a secondary character, adjoining other N. and S. joints intersected by oblique joints dipping N. W. at an angle of 60°.

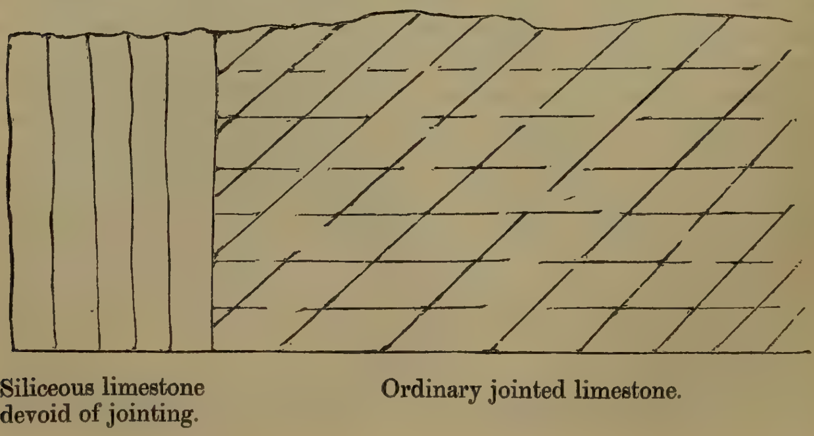
In most of the quarries and cuttings around Cork, the limestones offer few traces of the original bedding; and in many places the stratification of these rocks is absolutely obliterated. To such an extent does this occur, that in many quarries there is not the slightest evidence of bedding to be found; and so regular are the north and south vertical joints, which cut up the limestone into strata-like masses, that, were it not for the information afforded by the general geology of the country as to the strike of the limestone-strata, these rocks would be regarded as having vertical strata striking north and south,—a conclusion as far as possible at variance with the true direction. As in many limestones of the Alpine countries and other districts which have been subjected to the operation of powerful forces, stratification has in most instances been here destroyed, and jointings appear to have usurped its place.

Although, for the most part, the Carboniferous limestones of the district around Cork exhibit these several forms of jointing in a very perfect manner, yet this is not in all instances the case. The mineral nature of the limestones seems to have a considerable effect on the perfection of the jointing. There are series of thin-bedded cherty limestones intercalated with the ordinary limestones, more particularly near their base. In the neighbourhood of Cork, these are seen on the Western road, in a small quarry east from Carrigrohnane. They also make their appearance in the old quarry at Glasheen, and, S.E. from this, at Summerstown. In the cutting on the Cork and Bandon Railway, contiguous to the Cork Station, they likewise occur. Near the Gasworks, immediately adjoining the south side of the road which runs south of this quarry, they present themselves; and also near the South Infirmary.

At this last locality, the thin-bedded limestones have masses of red chert in them, which put on much of the aspect of jasper. Beds of a like cherty character, and containing masses of white chert, may be seen in the cutting of the Cork and Passage Railway, at the first bridge south of Black Rock Station; from this they extend eastward, and are again seen at Little Island, immediately south of the quarries which are now worked there. A red limestone in some instances marks these cherty bands; and, where this is the case, the general E. and W. strike of the limestone-strata is well manifested. In all instances, however, where the cherty limestones occur, they afford evidence of the strike of the Carboniferous limestone conforming with that of the underlying Devonian rocks. In these cherty limestones, jointing is far from being well shown. The north and south courses are apparent; but these are generally more remote from each other than in the ordinary limestones. The horizontal series is seldom exhibited, and the oblique series is equally absent.

At Summerstown, previously referred to, there are two quarries, which are not more than a hundred yards from each other. The one on the south-east exhibits the limestones intersected with the three courses of jointing, and has all traces of stratification oblite-

Fig. 7.—*West face of the Glasheen Quarry, showing the ordinary jointed Limestone on one hand, and the bedded and not-jointed siliceous Limestone on the other.*



rated. The other, which is in cherty limestone, has only imperfect N. and S. joints, but has the stratification very apparent.

At Glasheen this is still better shown. On the west face of the quarry here the point of contact of the two forms of limestone, differing in their lithological nature, is seen. On the northern portion of this west face, the ordinary limestone occurs cut up by the three courses of jointing; but, this face being at right angles to the more prevailing north and south series, this course is not visible, although well seen on the north face of the quarry. On the southern portion of this west face, the cherty limestones are devoid of visible jointing, but show bedding in considerable perfection. The forms of structure here seen are exhibited on fig. 7.

The effect produced by the difference in the mineral nature of the limestones, is also well seen in the lower portion of these strata, as they occur at Hawksglen, near Raffeen, about a mile and a half W.S.W. from Monkstown. Here the limestone is of the cherty kind, with almost vertical strata, having an east and west strike and subject to coarse cleavage. Jointing is very imperfectly represented, only slight traces of the N. and S. series occur, and very widely remote horizontal joints. To such an extent is this the case, that the limestone is wrought along the planes of its coarse cleavage, which strike east and west; and large flaggy masses are obtained by this mode of working, a circumstance which could not occur had the limestone in this spot been much intersected by divisional planes in the form of joints.

That the lithological nature of the limestone has a great effect on the character and extent of the joints, is made still more manifest by the analyses which were made for me by my friend and colleague Dr. Blyth, and of which the following are the results. A siliceous limestone, taken from the cutting of the Cork and Bandon Railway, near the Cork Station, a locality already alluded to, and where the *stratified* limestones are well seen, yielded the following analysis (the specific gravity being 2·677):—

| | |
|---|---|
| Carbonate of lime | 78·6 |
| Silica | 14·6 |
| Carbonate of magnesia | 5·5 |
| Iron | 1·3 |
| | 100·0 |

In this limestone the jointing was imperfect, only widely remote north and south joints making their appearance.

A specimen of jointed limestone from the Gasworks quarry, about a hundred yards N. E. from the cutting where the siliceous limestone was procured, furnished the following results (the specific gravity being 2·7):—

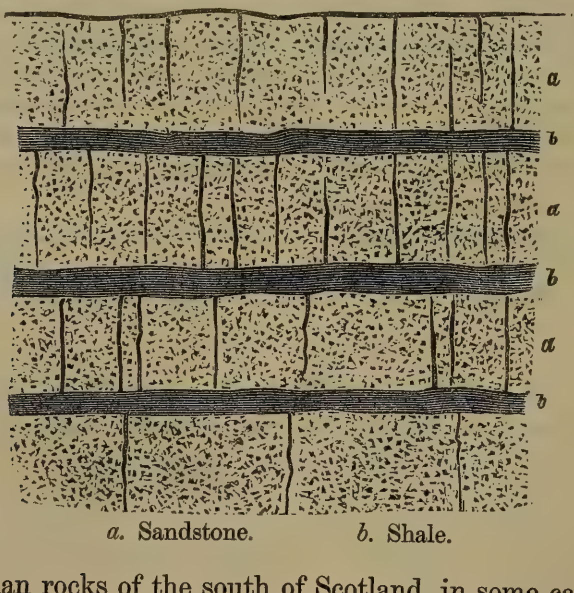
| | |
|---|---|
| Carbonate of lime | 98·50 |
| Carbonate of magnesia | 0·25 |
| Silica, iron, and loss | 1·25 |
| | 100·00 |

These two analyses show the important bearing which chemical composition has on jointing; justifying the conclusion, so far as the limestone of this neighbourhood is concerned, that the perfection of the jointing is in proportion to the purity of the limestone.

*Jointings in other rocks.*—That the lithological character of the rock is a matter affecting the nature of the divisional planes known under the name of joints, is in many instances well shown in rocks which do not appertain to the Carboniferous series, and in which limestones do not occur.

Among the arenaceous sandstones which constitute the Triassic formation of Cumberland, the effect of a difference in mineral composition is in some localities well seen. One of these localities is at the quarries of Howrig, near the Curthwaite Station on the Maryport and Carlisle Railway. Here we have thin-bedded red sandstones, dipping 12°, N. by W.; and these sandstones are generally intersected by vertical joints, which have a N. and S. course. The joints in each stratum commonly terminate with the bed. The strata of sandstone are either separated from each other by a thin parting of red shale, or have more argillaceous matter entering into their composition near their bounding places. In either of these cases, the presence of this argillaceous matter produces an effect on the jointings, rendering them less perfect and more indistinct in the more argillaceous portions. The result of this change in lithological character is represented in fig. 8.

Fig. 8.—*Jointing in Triassic Sandstone, Howrig, Cumberland.*



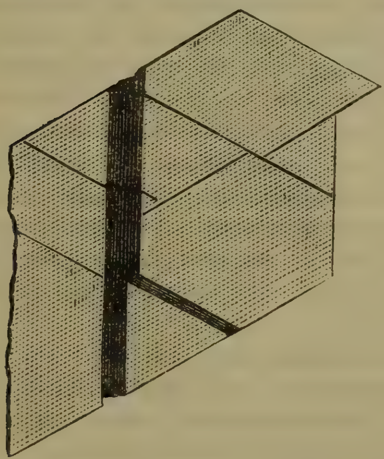

*a.* Sandstone. *b.* Shale.

The Silurian rocks of the south of Scotland, in some cases, exhibit the effect of various mineral characters on jointing. In Clunnie quarry, in the parish of Troqueer, in the Stewartry of Kirkcudbright, about $2\frac{1}{2}$ miles west from the town of Dumfries, this is beautifully represented; the strata here being of greywacke-sandstones and shales, the latter highly indurated. On the north side of this quarry, the beds, consisting of gritty rocks dipping N. at 60°, are intersected by N. and S. joints, nearly vertical, but in some cases inclining somewhat to the east.

These N. and S. joints are, on the whole, remote from each other, and they are the only series which make their appearance in the gritty strata here. On the south side of the quarry, beds of a more shaly character occur, having the same inclination as the grits on the north side. Here, however, the jointing is much more complex; and, as the thin shaly strata vary in their mineral nature, with every variation we have modifications in the jointings. On one bed of purple shale, fine in grain, the N. and S. joints are seen in close proximity, but having a shorter course than in the gritty strata; and in a layer of fine drab-coloured shale, which lies about 9 inches below the shale with the closely approximated joints, systems of jointings occur as complex and as perfect in their arrangements as any which make their appearance among the Carboniferous limestones of Cork, but without effecting that obliteration of original stratification, which is an attendant on the complex series of jointing in the limestones.

The complex series of joints pervading the fine drab shales at Clunnie quarry have their planes so approximated that hand-specimens afford very perfect examples of these planes; and an example is here figured with three distinct, well-marked series of jointing-planes, having a disposition to cut the shale into a succession of rhombs (fig. 9); and this example makes it manifest that mineral matter totally different in its nature from limestone has, from the forces which produce jointing, assumed an arrangement in its divisional planes which, in most respects, agrees with those of the purer limestones; but in the shale, if more minute jointings can be regarded as indicating a higher development of the force producing this structure, we have a complex mineral structure exhibiting more perfect joints than even an almost pure carbonate of lime.

Fig. 9.—*A piece of Jointed drab-coloured Shale, from Clunnie Quarry, Troqueer, Kirkcudbright.* Half nat. size.



*The threefold Jointings near Cork.*—In the allusions which have been made to the three forms of jointings which are common to the limestones of the district around Cork, it is by no means intended to convey the idea that, in all instances where the threefold series occur, one is vertical, having a N. and S. course, the second horizontal, and the third oblique, inclining at an angle of 45°. These can only be regarded as the typical modes of occurrence and the general aspect which these jointings assume. Considerable modifications sometimes take place. The E. and W. oblique courses in some cases incline at a greater, and sometimes at a less, angle; and the horizontal series has its place supplied by joints which are also more or less inclined. There is, however, in all these modifications of direction a great tendency of the joints so to arrange themselves mutually as to cut the masses included between the divisional planes into rhombs having their acute angle 45°. The form of the angles which result from joints, bear greater affinity to those which crystallized carbonate of lime assumes, and would, to some extent, support the inference, that, while the vertical N. and S. joints which intersect the limestones (with their various chemical compositions) are common to them and the underlying arenaceous Devonian beds, and must have resulted from the same causes, the oblique and horizontal joints (and their modifications, which appertain only to the purer limestones) are the products of another cause; and this cause would seem to be that which produces crystalline arrangement in carbonate of lime. There are two circumstances, however, which seem hostile to this inference:—one is the finely-developed jointing which manifests itself in the drab shales of Clunnie quarry, already referred to, where the chemical nature is far from homogeneous, and where no crystalline arrangement could result; the other is the limestones themselves possessing none of that cleavage which is an important feature in crystallized carbonate of lime.

*Fossils affected by the Jointings.*—There is another circumstance in connection with the jointing of the limestones which requires notice. This is, the condition of the fossils which occur in these deposits. Where we have the N. and S. joints well developed and closely approximated, and where fossils make their appearance in the limestones intersected by these joints, the fossils are very commonly more or less distorted. To such an extent does this prevail, that it is rare to find any species of the most common gasteropod, *Euomphalus*, in its normal condition. Almost every individual has an excentric form; and this deviation from the normal condition occurs likewise in brachiopods. *Spirifera striata*, the most common of these, is usually much distorted, and in some cases as far removed from its original state as any specimen of this shell which may be distorted by slaty cleavage.

Observations on these distorted shells *in situ* lead to the inference that the distortion has taken place between the jointings which have the N. and S. courses,—the shells being elongated towards the divisional planes, and flattened at right angles to these planes.

In other words, the elongation has been in an east and west direction—or in what would have been the strike of the slaty cleavage, had this structure affected these rocks, which it does not—and not in the direction of the dip of the cleavage-planes, the mode in which such fossils are elongated which have been subjected to distortion from slaty cleavage.

*Age of the Jointings.*—With regard to the subject of the relative age of the joints which affect the deposits in this locality, the only matters for comparison are the induration of the rocky masses, and the superinduced structure, slaty cleavage, which occurs in such rocks as are not highly calcareous. With reference to the appearance of joints in these rocks anteriorly or posteriorly to their induration, it may be observed that the evidence as to the age of jointing relative to these conditions, most strongly supports the conclusion that jointing has taken place after the consolidation of the rocky masses. Fossils are in many instances cut through by the joints; and not only fossils, but in some portions of the South of Ireland, as in the county of Waterford, and at Mount Misery on the east side of the Suir, immediately opposite to the town of Waterford, coarse conglomerates, containing quartz-pebbles, are intersected by joints which cut the quartz-pebbles as clean as if a lapidary's wheel had been the instrument effecting this cutting (see Sir H. De la Beche's 'Geological Observer,' p. 628); a circumstance, which it is difficult to imagine could have taken place had these pebbles been in the condition of loose fragments imbedded in soft sand.

The great regularity which prevails among the joints, and the parallelism which exists among members of the same series, are also antagonistic to the supposition that this structure affected rocks anteriorly to their consolidation; and indeed the whole features which pervade these divisional planes, are more favourable to the conclusion that jointing has affected rocky masses subsequent to their consolidation.

Concerning the relative age of the jointing and the slaty cleavage which is so common and well-developed in the Devonian rocks of the county of Cork, some information is afforded by the deposits of this age; and, as the same series of N. and S. joints are common to both the Devonian and the Carboniferous strata, the deductions which can be obtained from the former equally apply to the principal joints of the latter. On the surfaces of the cleaved strata, that rugose appearance which frequently presents itself on such surfaces, is very apparent, and has somewhat of the aspect of ripple-markings. Joints cut across these rugose surfaces, in such a manner as to show that the roughened structure was not induced subsequently to the formation of the divisional planes; as the joints intersect and separate what would have been continuous ridges and hollows, but for the interference ot the jointings; leading to the conclusion that this rugose structure, the result of cleavage, existed anteriorly to the intersection of the rocks by joints. There is another feature, in connexion with cleavage and jointing, which still further supports the inference as to the posterior age of joints. This is the smooth nature of the sides of the latter; for, had they existed anteriorly to the cleavage, in an approximated condition, such as that in which they now present themselves at many spots, it would be difficult to conceive their retaining the smooth character of their sides; since the force which gave rise to cleavage, and which caused the extension of the mineral matter of the rocks in the direction of the cleavage-planes producing the rugose structure, would have produced a like structure on the sides of the open joints; as these joints would have afforded facilities for extension rather than the planes of stratification.

*Cause of the Jointings.*—With regard to the source to which jointing is to be attributed, this is a matter which is, as yet, involved in considerable obscurity.

Prof. J. Phillips has described the series of joints which are so well developed among the sedimentary rocks of Yorkshire, and also pointed out the effect of a difference in the mineral composition of the rock on these joints*, but without, however, assigning a cause for the occurrence of these structures†. Sir Roderick Murchison has also noticed the results of varying lithological composition on jointings, and has also observed, that among the Silurian rocks, joints alter their direction with every change in the axis of elevation. He still further remarks that rocks "have a jointed structure, the result of crystalline action, and that the divergent directions in which the joints are arranged is the consequence of the mechanical process of elevation‡." On the subject of joints, Prof. Sedgwick§ observes, that while cleavage is the result of crystalline action, joints have their origin in mechanical causes. The latest observations which we have on the phenomena of jointing, and the forces which have given rise to them, are to be found in Mr. Jukes's 'Manual of Geology,' 1857, and as his observations have to a great extent been derived from the south of Ireland, they have an important bearing on the district under review. Mr. Jukes is to some extent disposed to attribute joints to the "natural result of the shrinkage or contraction of rocks upon consolidation‖;" but, when alluding to the extensive joints which make their appearance on the north side of Bantry Bay, and to others of a like character, he remarks, that "such unlimited joints were very probably produced, not from any internal shrinkage on the mere consolidation of the beds, but from a simultaneous yielding of the whole mass to a great expansion or stretching force¶." These theories resolve themselves into the consideration of two forces,—the one crystalline, and the other mechanical. This latter, however, presents itself to us in two aspects,—the one acting by compression, and the other operating in an almost opposite manner,—namely, by simple shrinkage from drying and consolidation. What has been said with reference to the cutting of the quartz-pebbles by joints in the Devonian conglomerate of the south of Ireland has a hostile bearing to the theory of consolidation in connexion with these divisional planes; and there are other circumstances which are antagonistic also to this hypothesis. Mr. Jukes himself finds that it is not calculated to account for the huge joints inter-

* 'Mountain-limestone of Yorkshire,' p. 94.

† Prof. Phillips presented, in 1834, "Notices" in reply to a question on this subject, proposed by the British Association in 1833. Report Brit. Assoc. 1834, Sect. p. 654. See also Hopkins, Rep. Brit. Assoc. 1838, Sect. p. 78.

‡ Silurian System, pp. 246, 247.

§ Synop. British Palæoz. Rocks, &c., p. 36.

‖ Manual, p. 193.

¶ *Op. cit.* p. 194.

secting the S.W. of Ireland, and it is equally inapplicable to the Devonian sandstones and the Carboniferous limestones of the area under consideration.

Mechanical force, operating in the form of pressure, seems to have been an agent more capable of producing these parallel planes. And, when we consider that this pressure has produced important changes on the particles of rocks which have been subjected to it in the south of Ireland, we may form some idea of the position in which rocky masses subjected to this force were placed. One of the proceeds of this pressure has been cleavage, the strike of the planes of which is nearly E. and W., and these planes have been elongated in the direction of their dip. Any mass of rock, the mineral nature of which was unfavourable to the production of cleavage-structure, if enclosed between two other masses, capable, from their lithological nature, of assuming a cleavage-structure, would be subject to compression, from the re-arrangement of the particles of the enclosing rocks undergoing this form of structure. The mass enclosed, so operated on, would have a disposition to extend itself at right angles to the *planes* of pressure; but, being rigid, the result would be the breaking up of this mass into a series of parallel joints, such as are exhibited by the N. and S. joints in the Devonian and the Carboniferous strata of this locality. The mode in which the fossils of the limestone are distorted, previously alluded to (p. 96), is a strong confirmation of the supposition that pressure exerted an important influence in the production of the N. and S. divisional jointing planes.

The effect of pressure, in connexion with rocks of the Carboniferous age, is still further manifested among the coal-measures of Kanturk in this county. Of these Mr. Jukes remarks:—"These coal-measures are commonly highly inclined and contorted, and often inverted; and the coals are not only changed into anthracite, but squeezed and crushed so as to be only got in small dice-like fragments. The regularity of the beds is also interfered with, so that the beds of which the original thickness was probably a couple of feet or so, have now for many yards only one or two inches, and then suddenly expand into large pockets of coal, twenty or thirty feet in thickness. Coal-mining here is conducted like vein-mining*." This is not the only change which the coal here has undergone.

It often presents an external form of a prismatic character, in which the bundles of the prisms are arranged at right angles to the laminæ of deposition; an aspect, which, if the coal possessed a semi-metallic lustre, would give it an appearance far more nearly resembling manganese than coal.

The whole strata in the neighbourhood of Cork have been subjected to violent forces; they exhibit contortions and flexures to a very great degree; and the pressure which must have arisen in consequence of these great disturbances, seems to have produced not only cleavage, but also a great amount of jointing. It is a matter of some interest

* Jukes's Manual of Geology, p. 445.

to observe, whether the occurrence and perfection of jointing are dependent, in other districts, on the amount of disturbance to which the strata have been subjected.

Mere pressure, however, fails to account for the complex systems of joints which occur in the purer limestones; and yet it is difficult to conceive that other forces have been in operation in the production of these complex series.

It appears probable, from the great purity of the more perfectly jointed limestones, that these, during their consolidation, had a disposition to assume a more crystalline nature than siliceous limestones; and that, on the application of pressure to these pure limestones, not only they obeyed the influence of the force which gave them, in common with the Devonian rocks and siliceous limestones, a north and south series of joints; but the pressure caused them to divide, in accordance with the mineral cleavage of calc-spar, and produced in them a disposition to assume a rhombohedral form. Although the case of the rhombohedral jointing of the Silurian shale from Clunnie quarry, before alluded to, seems somewhat antagonistic to this theory, yet the uniform size of the angles of masses intersected by the complex systems of joints, their angles agreeing with those of the cleavage-planes of calc-spar, and the pure mineral nature of these limestones, support the opinion that mineral cleavage is in part an important agent in the production of complex series of jointings in limestones.

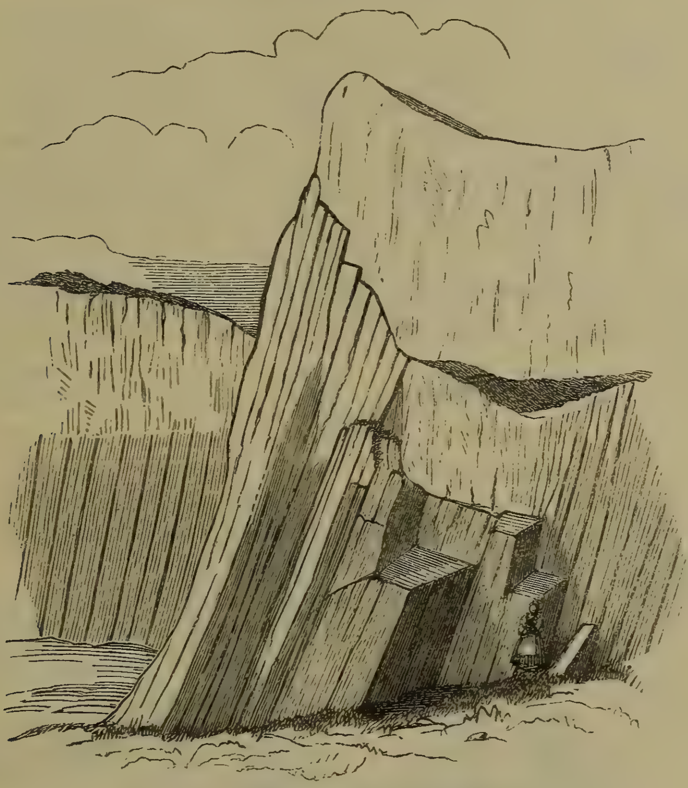
## On the Dolomites.

*Condition of the Dolomites near Cork.*—The connexion between jointing and the occurrence of magnesian limestone will, at first sight, appear very remote. When, however, we come to examine the divisional planes in many localities in the district around Cork, it will appear that the presence of joints has had a great influence on the occurrence of dolomites in the Carboniferous strata of this neighbourhood. The mode in which the magnesian limestones make their appearance, in the district under review, leads to the inference, that the dolomites were not deposited, by the ordinary action of water, as sedimentary rocks, but that they are superinduced structures, which have not only arisen from the action of forces operating subsequent to the deposition and consolidation of the limestones in which they occur, but have had their origin after the operation of that force which has produced joints among these limestone-strata.

In order to understand the mode of occurrence, and the circumstances which have given rise to the production of these dolomites, it will be necessary to detail some of the conditions under which they appear.

In the quarry near the Gasworks, which has been already alluded to (p. 93), several masses of dolomite are seen; and these exhibit such an aspect as to indicate that their mode of occurrence has little connexion with the original bedding of the grey limestone, of which this quarry for the most part consists. On the south side of this quarry three very distinct masses of yellow magnesian limestone are seen. One of these masses is represented in fig. 10. The bedding

Fig. 10.—*Dolomitic Carboniferous Limestone, at Gasworks Quarry, Cork.* Looking South.



The central light-tinted rock is dolomite

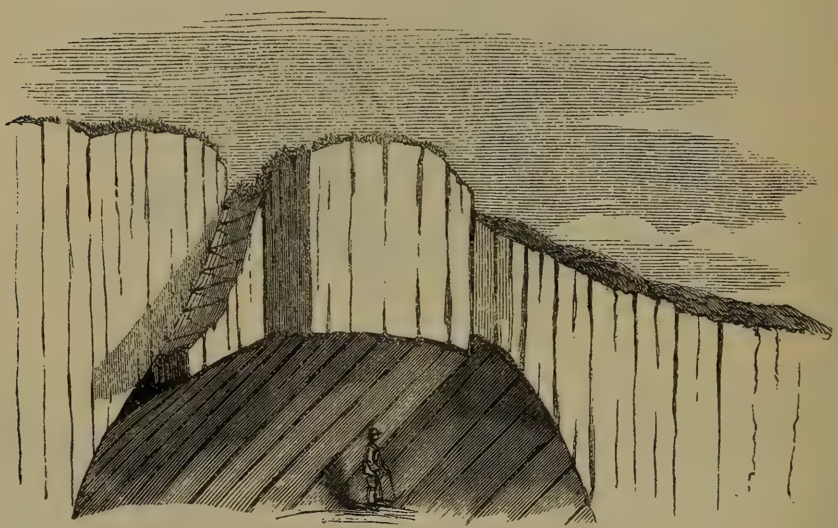
of the whole of the strata in this quarry, as before mentioned, is very indistinct; but the general strike of the beds supports the conclusion that the strata have an east and west range; and, consequently, the inclination of the strata must be either north or south, unless they be vertical. This arrangement of the stratification would lead us to expect that the dolomites would strike east and west also, parallel to the ordinary limestone-strata, had these dolomites originated from the same circumstances which have given rise to the other limestones. So far is this from being the case, that we have the dolomitic masses striking *north and south*; and, as the jointing is well developed in this quarry (more especially the north and south joints), we find an intimate agreement between the direction of the joints and the courses which these masses of dolomite assume. These features, as to direction, are not confined to the Gasworks quarry; the same phenomena are apparent at the larger quarry at Summerstown, also previously referred to (p. 92), and here likewise the jointing is well developed.

Hand-specimens can be obtained which exhibit the intimate connexion between the direction of the joints and the courses of the magnesian limestones. In some instances the line of the joint, when this joint is closed, forms the boundary between the dolomite and the ordinary limestone; the two distinct portions terminating abruptly against the sides of the joint.

All the circumstances in connexion with the mode of occurrence of these magnesian limestones support the conclusion, that in this locality jointing was antecedent to dolomitization, and has given to this form of limestone its peculiar north and south direction.

The strike of the dolomites is not, in all instances, in this locality, confined to the direction of the joints. In the smaller quarry at Summerstown (the one in which, owing to the thin-bedded and siliceous nature of the limestone, jointing is not very apparent) dolomite is also met with; but here, instead of having the north and south course, so common in the district, it is found striking east and west, conforming to stratification. Fig. 11 exhibits this mode of the

Fig. 11.—*Dolomitic Carboniferous Limestone, at Summerstown, Co. Cork.*



The tinted bands are dolomitic.

occurrence. The strata are vertical, and have a yellowish colour from weathering. The dolomite, however, is brown*.

Phenomena of a like character, in connexion with jointing and dolomitization, have been well described by Mr. Wyley as common in the county of Kilkenny, among the Carboniferous limestones†. From Mr. Wyley's sections and descriptions, it would appear, that in this country also, there is great reason for inferring, even when dolomites conform to stratification, that this substance cannot be regarded

* I am indebted, in a great measure, to Mr. F. Jennings for having pointed out these localities to me.

† Journal of the Dublin Geol. Soc. vol. vi. p. 109 *et seq.*

as having been originally deposited in the condition of carbonate of lime and carbonate of magnesia.

*Causes and Date of the Dolomitization.*—The whole aspect of these Carboniferous dolomites of Cork and Kilkenny, leads to the inference that certain changes have been effected on previously-existing masses of carbonate of lime; and the general parallelism which occurs between these dolomites and the main joints, and also the intimate connexion which exists between them, support the conclusion that this change was produced after the operation of those forces which gave rise to the phenomena of joints.

With regard to the causes of this subsequent change, we find nothing, in connexion with the carboniferous strata of the county of Cork, to support the inference of Von Buch, that igneous masses are the means by which dolomitization has been effected; nor is there any evidence, among these Carboniferous rocks, to show the action of such a degree of heat as usually produces metamorphic phenomena. The general thickness of these magnesian limestones in no way supports the conclusion that the cause producing them operated from below; nor do we meet with anything in connexion with these masses lending any support to such an opinion. On the contrary, we often find the dolomites thickest in their higher position; and these are circumstances which would rather lead to the conclusion that the cause producing dolomitization was external.

The only agent we know of capable of acting from above, in such a manner as to produce changes of a character rendering ordinary limestone dolomitic, is sea-water. This, from the abundance of magnesian salts which it contains (averaging 8·56 of chloride of magnesium, and 6·53 of sulphate of magnesia, in 100 parts of solid contents in the water of the German Ocean), is capable, under certain circumstances, of producing important influences on calcareous rocks. According to the observations of Regnault*, brought under my notice by my friend and colleague Dr. Blyth, the latter salt, sulphate of magnesia, in solution, at a temperature of 200 Celsius, possesses the power of decomposing carbonate of lime, producing sulphate of lime and carbonate of magnesia: and the reverse also takes place, under like circumstances, when sulphate of lime and carbonate of magnesia are brought in contact. Even at ordinary temperatures this latter change takes place. " According to Suckow, the efflorescence of sulphate of magnesia in the vicinity of Jena depends upon the decomposition of carbonate of magnesia, contained in bitter-spar, by means of gypsum †."

From these observations of Regnault, the action of sea-water on ordinary limestones, at considerable depths, where subjected to great pressure, and at an increased temperature, would exert its influence on these substances in such a manner as to produce important changes on limestones, rendering them dolomitic. This influence of magne-

* Cours de Chimie, vol. ii. p. 639.

† Bischof's Chemical and Physical Geology, vol. i. p. 430.

sian salts in solution in sea-water, as dolomitizing agents, has been noticed by Mr. Sorby*.

In the case of the magnesian limestones taking the direction of the joints, we have evidence of sea-water finding its way into these fissures, and penetrating the limestone-masses from these joints; and in the case where the dolomites conform to the stratification, as in the case of the thin-bedded siliceous limestones which are only partially jointed, the sea-water appears to have had access into the lines of stratification, and to have given to the strata, to some extent, a dolomitic character; such as, at first sight, would appear to have resulted from a combination of carbonate of lime and carbonate of magnesia held in solution by water, and gradually deposited therefrom in the usual manner, under which calcareous rocks have commonly originated.

In connexion with the inference which attributes dolomites to the decomposition of magnesian salts in sea-water, it is important to observe, that, even in cases where we have regularly-bedded dolomites, these have very frequently associated with them gypseous strata; a circumstance, which leads us to conclude that, even in the case of stratified magnesian limestones, these owe their dolomitic nature to the same decompositions which produce dolomites from consolidated ordinary limestones. In the stratified dolomites we have, however, the product of the decomposition, gypsum, intimately connected with the other product, magnesian limestone; a circumstance, which could not take place under such conditions as give rise to dolomitization in such calcareous rocks as have been consolidated and fissured in the form of joints antecedently to the operation of that force which produced magnesian limestones from ordinary calcareous rocks.

P.S.—Since the foregoing communication was read before the Society, the memoir of the Rev. Prof. S. Haughton, "On the Physical Structure of the Old Red Sandstone of the County of Waterford, considered with relation to Cleavage, Joint-surfaces, and Faults," communicated to the Royal Society, has been published. In the portion of this memoir which has reference to Joints, Prof. Haughton has also arrived at the conclusion that these structures were produced subsequently to the consolidation of the rocky masses which they intersect; and also after the cleavage-planes had manifested themselves in the strata of the district (Phil. Trans. for 1858, p. 338).—R. H., January 1859.

* Report of Brit. Assoc. 1856, Trans. of Sections, p. 77.

## 2. *On an* Experiment *in* Melting *and* Cooling *some of the* Rowley Rag. By W. Hawkes, Esq. (Communicated by the President.)

[Abstract.]

About 31 cwt. of basalt was melted in a large double reverberatory furnace; and after a slow cooling during thirteen days, it presented an upper stratum of stony vesicular matter about 1 inch thick, next a layer of black glass from 2 to 8 inches deep on that side of the mass which was exposed to the air from the door of the furnace; elsewhere, immediately under the vesicular layer, was solid stone, interspersed here and there with air-bubbles. Mr. Hawkes added some observations relating to the results of experiments which he had made to ascertain the temperature of melted cast iron, and of melted basalt.

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## 3. *On the* Iron-ores *of* Exmoor. By Warington W. Smyth, Esq., F.R.S., Sec. G.S.

Much attention has been bestowed, during the last seven years, on the exploration of veins of iron-ore in that hilly tract of country in Devonshire and West Somersetshire, which extends from Ilfracombe on the west, to near Bridgewater on the east. Its dominant points, on Exmoor, rise to an elevation of from 1400 to 1600 feet above the level of the sea, whilst the greater part of the region in question is of so considerable a height, that the deeply-cut valleys, or combes, through which the numerous streams find their way to the craggy coast, have long earned a deserved celebrity for the landscape-scenery of North Devon.

The district in which, at intervals, iron mines have been opened, is a belt of about five miles in width and about thirty in length, forming a part of the "Greywacke Group" of Sir H. De la Beche*, and of the equivalents of the "Plymouth Group" and a portion of the "Dartmouth Group" of the Devonian series, as described by Sedgwick†.

If, from Linton, where the lower beds of the range may be examined, the observer travel southward, he will pass over a constantly ascending series of strata, and about Simonsbath, on Exmoor, will reach the line of irregular lenticular deposits of limestone, which, trending from Combe Martin by Challacombe, through the midst of Exmoor, to Cutcombe and Treborough, furnish an indication of the general strike of the district, and a supposed parallel to the more massive limestones of Plymouth. To the north, or, in other words, beneath these calcareous bands (which are far from continuous), a few of the metalliferous repositories occur: most of

* Report on Cornwall and Devon, p. 89.
† Quarterly Journal Geol. Soc. vol. viii. p. 3.

them are situated among the beds overlying, and therefore south of, the so-called "calciferous slates."

Ores of iron occur both in regular strata and in veins; and it is evident that they were known and worked by our forefathers, although the common tradition of their having been opened by the Romans, and the term "Roman vein" attached to one locality, would seem, I think, of less weight than the probability of their having been wrought about the time when Queen Elizabeth invited German miners to England, supported as it is by the name *Eyesen* Hill, by which one of the ancient workings is still known.

The ores occurring in strata have been found (especially on the flank of the Hangman Hill near Combe Martin, in the valley of the Exe, north-east of Simonsbath, and in the North Forest, Exmoor) in nodules, generally of small size, and often tilted, with the shales in which they occur, at such considerable angles as to render their working difficult. An uncommon variety, of chocolate- or claret-colour, and with an unusually high per-centage of iron, is seen in the North Forest.

The lodes, or iron-bearing veins of this country, course almost uniformly about E. 10° S., inclining at an angle of from 45° to 65° southward, and hence appearing to hold so exact a parallelism with the strata, as to have been regarded by some observers as stratified deposits. A closer examination shows us slight deviations from such parallelism, both in strike and dip, as well as those irregularities of composition which are so characteristic of lodes. It is owing to this latter variability, and to the want of familiarity with similar capricious lode-phenomena, that some disappointment has attended the operations hitherto attempted. Very few of the works have as yet been pushed to any considerable depth or length; but all the more extended excavations have exhibited an interesting series of subjects for observation in addition to those above-mentioned.

First, hæmatite-ore, or the anhydrous sesquioxide of iron, has been obtained from near the surface of certain veins in the property of Fred. Knight, Esq., M.P., especially from the Roman lode, Cornham Ford, and Little Woolcombe, exhibiting small crystals of specular iron, but with a structure throughout the mass distinctly resembling that of sparry iron (carbonate).

The analysis of that of Cornham Ford, by Mr. Riley of Dowlais, is as follows:—

| | |
|---|---|
| Peroxide of iron | 98·41 |
| Silica | 1·01 |
| Oxide of manganese | 0·29 |
| Magnesia | 0·16 |
| Phosphoric acid | 0·12 |
| Moisture | 0·13 |
| Oxide of copper | 0·04 |
| Nickel and alumina | trace |
| | 100·16 |

A large proportion of the red ore or hæmatite is also mingled in the Hoar Oak veins, and in Rogers's and other lodes in the Deerpark, near the surface. The main portion, however, of their contents, particularly distinct in the numerous parallel lodes which occur in the Deerpark, situated about one mile and a quarter south of Simonsbath, consists of brown or hydrous peroxide of iron, in a state of great purity, as evinced by the millions of little prismatic crystals of "goethite" lining the interior of numerous cavernous hollows which are interspersed amid a mass bearing evidently the general rhombohedral structure of sparry iron.

Mr. Riley's analysis of the ore of "Rogers's lode" is as follows:—

| | |
|---|---|
| Peroxide of iron | 71·34 |
| Peroxide of manganese | 16·79 |
| Silica | 1·49 |
| Alumina | 1·10 |
| Lime | 0·13 |
| Magnesia | 0·22 |
| Phosphoric acid | 0·33 |
| Combined water | 7·98 |
| Moisture | 0·79 |
| Oxides of nickel and cobalt | 0·19 |
| Oxide of copper | 0·05 |
| | 100·41 |

The workings in this latter lode have proved it to consist, in a width of from 2 to 13 feet, averaging probably 9 feet, of a loosely agglomerated goethite, with much the same character throughout, occasionally intermingled with bands of quartz and fragments of the adjoining slate-rock.

At Hangley Cleave, on the extreme south of the moor, a vein, 15 to 20 feet wide, of botryoidal and cavernous brown-ore intermingled with quartz and slate is succeeded, at the depth of a few fathoms only, first by single nuclei, and further by masses, of a pale-coloured and compact sparry ore.

The most extensive operations have been carried on at Raleigh's Cross, in the Brendon Hills, where the lode, from 2 to 20 feet wide, dips 45°, and, as it approaches the west, 65° south; in the footwall it carries a rib of quartz 3 to 6 feet wide, and in places is so much occupied by the same mineral, as, for fathoms together, to be useless as an iron-lode. Its ore is mostly a cellular cavernous mass of brown iron, with occasional portions of goethite; whilst, at the depth of 140 feet from the surface, irregularly isolated masses of sparry iron-ore come into sight, and indicate that the whole lode once consisted of that mineral.

At Goosemoor, a little further west, a deep level has intersected a vein, which, although opening and closing in courses of lenticular form on a large scale, yields an excellent sparry ore, of which the following analysis was made in Dr. Percy's laboratory:—

| | |
|---|---|
| Peroxide of iron | 0·81 |
| Protoxide of iron | 43·84 |
| Protoxide of manganese | 12·64 |
| Lime | 0·28 |
| Magnesia | 3·63 |
| Carbonic acid | 38·86 |
| Water | 0·18 |
| Insoluble residue | 0·08 |
| | 100·32 |

At Eyesen Hill, intermediate between this point and Exmoor, the lodes run much in the usual strike of E. by S., with a dip of 60° S., but are unusually curvilinear for short distances, and, thus, "bunchy" as regards their productiveness, being at times pinched up to a few inches, and rapidly opening to 8 feet in width. They yield excellent brown ore, of the variety called pitchy ore (Eisenpecherz); and the occurrence of a small vein on the east side of the hill, coursing N.N.E., is additional evidence in favour of the true vein-character of these deposits.

A very important lode still to be noticed is that of Huel Eliza, worked some years ago, in the valley of the river Barle, for copper-ore, but presenting in depth a mass of sparry iron-ore, with small disseminated portions of copper-pyrites, in a manner similar to that of some of the veins in the noted iron-district of Siegen and Müsen, near Bonn. Brown iron-ore, ceding in depth to the carbonate, occurs again in similar veins at Kentisbury Down.

The principal geological results derived from an examination of these lodes appear to be—

1st. That a series of parallel fissures have been opened in planes very nearly concordant with those of the general stratification, and have then been filled with carbonate of iron, some quartz, and fragments of the containing rock. Some of these, with the slates, have afterwards been subjected to various disturbances, the results of which are seen in heaves and slides, as at Goosemoor, near Bearland Wood, &c.

2ndly. This ore has (and in some places to a very great depth) been entirely metamorphosed into goethite, or pure hydrous peroxide—the carbonic acid being removed, and the oxide of manganese, which was originally as a carbonate involved in the same compound, occurring in the new ore as a peroxide,—whilst the rhombohedral structure is still distinctly shown in the entire mass, and the cavities formed by the decrease of bulk consequent on the change have given occasion to the appearance of innumerable brilliant acicular crystals of goethite.

3rdly. Some portions of the same vein-stuff, and, as it would appear, only near the surface, have been changed into hæmatite, the same original structure being preserved; and it is a question whether such portions have not passed through the intermediate conditions of brown peroxide.

4thly. The occurrence of rounded pebbles of hæmatite in the lower beds of the New Red Sandstone which skirts the north-eastern side of these hills, indicates the probability of such rounded stones being derived from the wearing-down of the lodes above described, and would, in that case, point to a date for their having been filled with ore at a period anterior to the great spread of oxides of iron which appears to have taken place in south-western England soon after the deposition of the coal-measures.

Of these points, the change of sparry iron-ore to the hydrous peroxide is one of very common occurrence, and is especially notable in Styria, Carinthia, Siegen, and those other countries where similar ores have been followed to a considerable depth from the surface.

The further change to the red peroxide shows itself less frequently with satisfactory distinctness; but at Somorostro, near Bilbao, and in several of the lodes of the Siegen district, most interesting examples may be obtained, in which the rhombohedrons, originally characteristic of the carbonate, now consist of hæmatite.

Dr. Livingstone brought with him from central Africa stones of iron-ore, picked up on the surface, which presented exactly the same series of changes. Some of these African pseudomorphous iron-ores were from the gneiss west of Loangua River; others from the Zambese, west of Tete.

The grand scale upon which this pseudomorphous action has proceeded is a reason for inviting attention to new instances, which may aid us to explain the formation of iron-ores in their natural repositories,—a subject still far from clear, notwithstanding the ingenious papers of Haidinger and Volger.

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## 4. *On* Arborescent Native Copper *in the* Llandudno Mine, *near* Great Ormshead, North Wales. By Captain William Vivian, of the Llandudno Mine. (Communicated by John Taylor, Esq., F.G.S.)

[Abridged.]

It is well known that copper, like some other native metals, sometimes crystallizes in filiform and arborescent shapes; but in these forms they are mostly diffused through masses of mineral gangue, or spread out upon the matrix, apparently unable to bear their own weight. The symmetrical forms, however, to which we now refer are seen by a microscope to stand up like a crystalline grove of trunks and branches.

The entire group is composed of separate crystals, strung out in axial lines; the crystals under high magnifying powers show the flat wedge-like octahedron; but there is no uniformity; each crystal, or spike of crystals, varies more or less in size and modification. In the small cavities containing these crystallizations, are associated crystals of ruby copper; the latter never run out into spikes or branching forms, but exist in single perfect or modified octahedrons, or are dotted about in irregular clusters of crystals.

The whole of these minute crystallizations occur in a bed of brown limestone, yielding a soft, rich, yellow bisulphuret of copper, —the rich ore, however, being very intimately mixed up with the crystalline limestone, something like the material of a fine-grained granite or porphyry. The ore contained in this bed seems to be a medium or transition between the harder and more sulphureous ore of the bed below and the carbonates and oxides of copper of the bed above. The copper crystallizations here are peculiar to this bed alone, and are doubtless the result of the decompositon of the ores of copper. We observe that the ore of this bed is saturated with a large quantity of moisture, which, if not the decomposing agent, no doubt facilitates the precipitation in these symmetrical forms.

What seems also worthy of remark is, that all these minute crystallizations of copper, whether ruby or metallic, have been formed subsequently to the lime-crystals: these latter are often seen tipped with an octahedron of ruby oxide, or overlaid with spikes of native copper, as described; but the lime never covers the different forms of copper.

*Note by W. W. Smyth, Esq., Sec. G.S.*—The minute arborescent crystals described by Captain Vivian are very similar to those from Bogoslowsk in the Ural, figured and explained by Gustavus Rose (Reise nach dem Ural, vol. i. p. 403). These are twin-crystals, which group themselves in three directions parallel to the three edges in which the cube-faces intersect one another in the common plane of contact of the twin, thus forming angles of 120° with one another. Subsidiary groups attach themselves to the above, in such wise that they form angles of 60° with the three chief directions; and, although the form is due to the grouping of a great number of individuals, the parallelism of their planes gives the whole the character of one large compound crystal.—W. W. S.

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5. *On the* Slate-rocks *and* Trap-veins *of* Easdale *and* Oban. By James Nicol, F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen.

In the Geological Map of Scotland a narrow band of clay-slate is laid down as skirting the eastern shore of Islay and Jura, and passing through Luing and Seil to Kerrera and the vicinity of Oban. This rock was fully described by Dr. Macculloch in his work on the Western Isles; and I should not have noticed it further, had not my observations led me to differ from him in some important points. My present remarks refer, however, only to this formation as seen on Seil and Easdale and in the vinity of Oban, and more especially to the former locality. This place has been long celebrated for its extensive slate-quarries, the property of the Marquis of Breadalbane. These works give employment to about 200 persons. They are chiefly situated in the small island of Easdale; and, the higher parts of the rock being exhausted, they are now carried on at a great depth below the level of the sea.

*Mineral character of the rocks.*—The slates extracted for roofing-purposes on Easdale and Seil are usually dark-blue or almost black, with a silky lustre. They are split along true planes of cleavage; but the thin laminæ are uneven and undulating. Their surfaces are thus often striated or wrinkled, similarly to what is named ripple-mark in other beds, but in this case clearly produced in an entirely different manner. Crystals of iron-pyrites (usually cubes, but with one axis often abnormally shortened) are dispersed in more or less abundance through these slates. As these crystals are not readily acted on by the atmosphere, they do not injure the durability of the slates; but, with the unevenness of the cleavage-planes, they prevent the slates from splitting so thin, or of such large dimensions, as in the Welsh quarries.

Mixed with these fine slates are other beds, of a coarser grain, almost fine greywackes, and showing so little of the fissile texture as to be unfit for roofing-purposes. Other beds contain a considerable amount of calcareous matter, and are known as "limestone" by the workmen. In these, veins of calc-spar and quartz, sometimes several inches broad, are irregularly dispersed. Similar veins of quartz and calc-spar abound in the slates near Oban, intersecting the strata in all directions—across, oblique, or parallel to the cleavage or the bedding. Another curious set of beds, well seen in Easdale, consist of a soft friable material, with a texture not firmer than decayed wood, so as to be cut readily with the knife, and to leave a mark on paper like black chalk. It burns white in the fire, and appears to contain a considerable amount of fine carbonaceous matter. Similar rocks, soiling the hands when touched, abound on the Sound of Kerrera near Oban, but are firmer in texture.

*Concretions in the slate; and Coal.*—Though the crystals of pyrites are generally diffused through the rock, they occasionally occur in greater abundance in certain beds or portions of the strata. Some beds also contain nodular masses or concretions, of various sizes, imbedded in the slate. These nodules contain a considerable amount of calcareous matter, and often also small veins of quartz. They are harder than the slate, and are destitute of the slaty structure*. In one of these beds, at a depth of 140 feet from the surface, a small mass of bituminous coal has been lately found. Some fragments of this coal were forwarded to me last winter by Mr. John White, the intelligent overseer of the Easdale quarries. In reply to some questions which I put to him, he informs me that the coal, of which he has a portion measuring $2\frac{1}{2}$ inches by $1\frac{1}{2}$ and 1 inch, was surrounded by a greasy or unctuous clay, such as is usually found in slight open-

* Some of these calcareous nodules are 3 feet or more in diameter; they lie in the plane of the strata, and chiefly in one bed. They affect the cleavage, which curves or bends round them. Some of them contain veins or layers of quartz; and one large mass has a curious twisted appearance, like a piece of soft paste squeezed through a narrow hole.—J. N., January 1859.

ings in the quarries. He says that the crevice or fissure where it occurred was not larger than a man's fist, and so completely shut in, that even water could not have found an entrance from the surface until the rock was broken up by gunpowder. Mr. White did not obtain the specimen himself, but is quite convinced that it was discovered in the place and under the circumstances stated.

The coal sent to me is highly bituminous, and burns readily, with a bright flame. In external characters it closely resembles the common bituminous coal of the Scottish coal-field. When examined under the microscope, it exhibits traces both of cellular and fibrous structure, sufficient to show its vegetable origin. Its occurrence in this position is very remarkable*.

*Supposed organic remains.*—The only indications of organic remains that I have observed, besides the carbonaceous matter above mentioned, are of a very uncertain character. On the exposed surfaces of some of the soft black rocks near Oban, markings occur like those of the annelids or fucoids seen in some of the older rocks. In general form they very closely resemble the *Palæochorda minor* of M'Coy†. Their true nature is, however, uncertain; and such rude and obscure forms can have little value in determining the age of the beds. From the same place I also obtained a curious conical body, like the fragment of an Orthoceratite, but too obscure to allow me to be certain even of its organic origin.

*Stratification of the slate.*—In the Easdale quarries, the slate forms beds of considerable thickness, well known to the workmen from the change that takes place in the quality of the rock in passing from layer to layer. The stratification is, however, very indistinctly marked, and is often so obscured by the cleavage, that it may be entirely overlooked without great care. The beds are disposed in great rolls or undulations, of which three at least are clearly seen; but, on the whole, they dip at a high angle to the west or north-west. In the rocks near Oban the stratification is more clearly marked, but with very great diversity both in the amount and direction of the dip. The beds, indeed, appear to have been so broken up and crushed together as to destroy all regularity in their position.

* Last summer (July 1858) I again visited Easdale, and examined into the facts in reference to this coal. The place where it occurred was pointed out by the workmen who found it. It was in the line of a very narrow crack or slip in the beds, scarcely more than $\frac{1}{10}$th inch wide, but reaching to the surface. This slip is nearly parallel to the cleavage, but transverse to the bedding. The coal was not enclosed in the solid rock, but in soft clay. On the surface of the mass of coal the vegetable structure is distinctly seen, as in the common coal from the central district of Scotland, of which it seemed to be a portion. It has, of course, no bearing whatever on the geological age of the slates; but the mode of its introduction into such a narrow fissure seems a problem of much difficulty.—J. N., January 1859.

† Sedgwick and M'Coy, 'Palæozoic Fossils,' pl. 1 A. figs. 1 & 2. These figures are very tolerable representations of a specimen in my possession. They are from the black slates of Skiddaw, in which Professor Sedgwick mentions the occurrence of carbon (Journ. Geol. Soc. vol. iv. p. 220). The mineral character of the beds thus adds to the probability that the Easdale slates belong to the same period with the Skiddaw slates.

The peculiar irregular disposition of the strata is well seen in many places along the Sound of Kerrera, where the beds are rolled up, as it were, into curves and broken cusps, so complex that words cannot describe them, and intersected by veins of white quartz and calc-spar.

*Slaty cleavage of the district.*—The slaty cleavage is, in general, very distinct, especially in the Easdale quarries. It seems to have been mistaken for stratification by Dr. Macculloch in the section of Seil, given in the 'Western Isles*.' In that work, also, we see but few indications that he had any clear notion of the peculiar characters of these two structures. He indeed refers to the distinction in one case, illustrating it by a figure, and even mentions "the facility with which the plane of the schistose division may be mistaken for that of the bed;" but it is curious to observe how seldom he alludes to the cleavage, and how little use he has made of the "criterion" of the alternation of mineral character, "to ascertain the position of beds of clay-slate," which he points out in the same place†. Both in Easdale and Seil the cleavage dips very regularly at about 60°, to E. 30° S. (true), but varies in some places by a few degrees both in amount and direction. It also changes its position in passing through the calcareous bands, in which it is flatter, or inclined at a lower angle. On Kerrera and near Oban, the rocks also show a strong and well-marked cleavage; but this is often conjoined with other imperfect cleavages, or planes of division developed in other directions. In some places near Oban three of these division-planes may be seen, besides the stratification, to which they are sometimes parallel, at others oblique or perpendicular. Two of the best-marked of these planes meet at an angle of about 70°. Where they are fully formed, the rock breaks into very irregular fragments. In this part of the formation also, we do not find that constancy in the position of the cleavage which prevails at Easdale. It varies very considerably, even in a limited section and in contiguous beds. Thus, in one section of only a few yards in length, I noted the following dips of the cleavage in separate beds, in descending order: the beds are marked by letters; and the dips are magnetic, and not corrected for variation. The dip of the beds *a* to *h* was 75° S. 35° E.; of the lower beds, *i*, *k*, 50° S. 37° E., as noted at the time.

| | | | |
|---|---|---|---|
| *a* . . Cleavage-dip | 57° N. | *h* first cleavage | 56° N. 15° W. |
| *b* . . . . . . . about | 65° N.? | second ditto | 30° S. 10° E. |
| *c* . . . . . . . | 16° S. 30° W. | *i* . . . . . . . . | 55° N. 10° W. |
| *d* . . . . . . . | 45° N. 10° W. | *k* . . . . . . . . | 48° N. 16° W. |
| *e* . . . . . . . | 15° S. 15° E. | | |
| *f* . . . . . . . | 65° N. 10° W. | Easdale . . . | 60° S. 30° E. |
| *g* . . . . . . . | about the same. | Ballahulish . | 65° W. |

This section (and it is by no means a solitary example) seems to me important in several respects. It shows that the cleavage-planes, even in alternating beds, may dip in opposite directions, in some

* Pl. xxii. fig. 1. † Western Isles, vol. ii. pp. 242, 243, pl. xxii. fig. 6.

instances to the S.E., more often to the N.W.; and that in one stratum (*h*) two cleavages occur, one in each direction. The strike of the cleavage, on the other hand, is very constant, from E. 10° or 15° N. to W. 10° or 15° S.,—the chief exception being in *c*, where it is W. 30° N., thus diverging full 40° from the others.

The average strike of the cleavage also varies fully 20° from that of the beds. It comes within 15° of the strike observed at Easdale, but, on the other hand, is nearly at right angles to that at Ballahulish*. On comparing the strike of the cleavage with the position of the great overlying masses of trap-rock in Mull and Lorn, no very intimate relation can be discovered. The Lorn trap, which is nearest, lies, in the case of Easdale, chiefly on the north-east; in that of Oban, on the south-east. On the other hand, both the direction of the strata and the strike of the cleavage have evidently a most intimate connexion with those far more ancient and deep-seated causes which have produced the most striking features in the present physical configuration of the country. They are nearly parallel, for instance, to the shores of the Linnhe Loch, to the Island of Lismore, and to the great depressions occupied by Loch Etive, Loch Awe, and Loch Fyne.

*Trap-veins of Easdale and Oban.*—Another remarkable feature of this locality is the great abundance of veins of trap. Being harder and less destructible than the rocks which they intersect, they often remain projecting beyond them, like ruined walls. Such trap-veins are common on the coast of Seil; and a very picturesque one may be seen near the bridge connecting that island with the mainland, built up of rude horizontal columns and overhung with ivy and wild flowers. In one visit to Easdale, I enumerated more than a dozen trap-veins on that small island alone; but there are many more; and, were the neighbouring part of Seil included, the number might be very greatly increased. From the manner in which they intersect, they are evidently of diverse age. Thus one vein of porphyritic basalt, on Seil, runs partly through the slate, partly through a kind of tufa-rock, and is, in its turn, intersected by another vein of blue-coloured amygdaloid. Here, therefore, we have trap-rocks of three periods at least. One set of veins, running generally parallel to the slates (and to which my attention was directed by Mr. White), are apparently the oldest, being intersected by all the others. These consist of an amygdaloidal claystone, containing many small round nodules of calc-spar. Its colour is ash-grey, with a slight tinge of

* It may be necessary to mention that the line drawn on the Map which accompanies the very ingenious memoir of Mr. D. Sharpe, "on the Foliation and Cleavage of the Rocks in the North of Scotland" (Trans. Roy. Soc. 1852, p. 445), represents apparently the position of the mineral masses as laid down on Dr. Macculloch's Map, and not the cleavage-planes, which are beautifully seen in the principal quarry, dipping W. by compass, and thus nearly at right angles to that line. I intended to have given an account of the slate-rocks of Ballahulish in this paper; but, although I have made three visits to that locality in different years, I have not been able to satisfy myself as to the exact relations of the rocks in that highly disturbed region.

green on the fresh fracture, but becomes reddish or greenish brown on exposure to the weather. The sides of the vein, for about an inch deep, are compact; but the centre is made up of rounded concretions, about the size of peas, separated by cavities with rough drusy surfaces. The more common veins run nearly at right angles to these and to the cleavage-planes, or from N.W. to S.E. (N. 53° W. to S. 53° E.). In mineral character they are generally fine-grained dark-coloured greenstones or dolerites, but are often porphyritic or amygdaloidal. They vary, even in Easdale, from a few inches to several yards in thickness, and in this and other respects show many interesting irregularities. Thus, some of them divide and ramify in most singular forms; another will thin out and disappear, but a similar vein, commencing a few yards to the side, and gradually increasing, forms, as it were, its continuation. One vein, 24 feet wide, of dark-grey greenstone was in one place cut off abruptly by the slate, and shifted 16 feet to one side. Some of the veins enclose fragments of slate, often of considerable size. In these pieces the cleavage is quite distinct, but lying in different directions, so that this condition must have been impressed on the slates before the intrusion of the veins. Where these trap-veins are of small dimensions, they do not seem to have greatly affected the slates; but where they are thicker, the slate is in some places more friable, in others hardened or converted into a kind of flinty slate.

*Pitchstone-vein.*—Another remarkable vein is seen on Seil, near the old Danish Fort. The main vein consists of greenstone; but it is accompanied, sometimes on one side, sometimes on both, by a thin layer of pitchstone, from half an inch to one or two inches wide. The greenstone-vein varies from one to three feet broad, but in one place is six feet wide, and is there intersected by the pitchstone-vein, which also becomes wider. I traced these veins for more than a quarter of a mile along the beach*. The pitchstone is very dark-green or black, with a prismatic structure and conchoidal fracture; in small fragments it has much resemblance to glance-coal, for which it might be mistaken. The occurrence of this mineral in this place is interesting, as forming a connecting link between that observed in Skye and Eigg and that of Arran and the north of Ireland.

*Connexion and age of the Trap-veins.*—The direction of the second class of trap-veins in Easdale points directly to Mull, and indeed to Ben More, the loftiest of the igneous mountains in that island. It might thus be supposed that they were connected with this focus of igneous activity. However, we find similar veins, and nearly parallel in direction (N.W. or N. 48° W.), both in other parts of Seil and on the Sound of Kerrera, near Oban, and thus with no tendency to converge to a centre. Besides, on the coast of Mull, between Duart Castle and Craiganure, I have observed two sets of veins running nearly parallel to those in

* In July 1858 I found the continuation of these veins in the small bay north of the village; and fragments of a similar pitchstone on the hills near Oban.—J. N., January 1859.

Easdale, and, so far as I noted them, apparently corresponding both in mineral character and relative age. One group were grey claystones, running nearly W.S.W. and intersected by other veins of dark greenstone, occasionally amygdaloidal, with a N.W. direction (N. 48° W.). In this place both sets of veins intersect liassic strata containing characteristic *Ammonites* and *Gryphææ*, and are thus shown to be of more recent date than these deposits. It thus appears that, subsequent to the Jurassic period, this region of Scotland has been rent by two distinct sets of fissures, one nearly parallel to the stratification, the other at right angles to the first and also to the bedding of the rock. Considering the trap-rocks of Airdnamurchan, Mull, and Lorn as one mass, the second line is nearly parallel to its longer axis, and also to the Sound of Mull; but I am inclined to regard these veins as more recent than the great body of overlying trap in this region. In truth, one of the most striking facts forced on the geologist in examining this portion of Scotland, is the conviction of the very recent date of many of the great convulsions by which its present physical outline has been produced. Thus, the mountain-cliff (1200 to 1500 feet high) forming the coast of Morven, between Ardtornish and the Linnhe Loch, consists half of the old gneiss, half of liassic strata and recent trap, brought side by side with each other along an enormous fault, and now smoothed down into one uniform mass.

*Conclusion.*—In conclusion, it might be expected that I should notice the probable age, and equivalents in other parts of the country, of the slate-rocks. They are, however, such a mere fragment, so broken up, and so unconnected with other stratified deposits, that little more than conjecture could be offered. I have been in the habit of identifying these slates with the band of clay-slate on the southern margin of the Grampians, which I have long considered to be the equivalent of the Lower Silurian slates of the south of Scotland. At present I am rather disposed to regard the Easdale and Oban slates as a higher and more recent deposit than the slates of Birnam and Dunkeld, although, as stated above, both the obscure traces of organic remains and the mineral character of the rocks might lead us to identify them with the Skiddaw slates of Professor Sedgwick, and thus with some of the lowest beds of the Palæozoic series. Near Oban they are covered unconformably by great masses of conglomerate and red sandstone, in their turn overlaid by trap; but the age of these beds is, perhaps, even more uncertain than that of the slates. They are usually classed as Old Red Sandstone, on the same ground that all the red sandstones and conglomerates of Scotland have been put into this category, but, it seems to me, without any good reason *. To discuss the age of these rocks would, however, lead into questions involving the structure of the whole north and west of Scotland, and thus quite beyond the object of the present communication.

* In my recent Geological Map of Scotland, I have classed these beds as being probably Trias,—the commencement of the Mesozoic series of the west coast.—J. N., January 1859.

June 23, 1858.

Handell Cossham, Esq., Shortwood Lodge, Mangotsfield, was elected a Fellow.

The following communications were read:—

## 1. *On some Points in the* History *and* Formation *of* Etna. By Dr. H. Abich, For. Memb. G.S.

[In a letter, dated St. Petersburg, March 3, 1858, to Sir C. Lyell, F.G.S., &c.]

Your questions about Etna have carried me back to the pleasant time when I made repeated studies of that remarkable mountain, not having a presentiment of the occasion which I much later had of verifying and recognizing in another land the truth of those beautiful laws of nature, written so clearly in the configuration of the Val di Bove, and especially in the structure of the very body of Etna, visible on the slopes and steep declivities of that enormous chasm of subsidence, the Val di Bove. For, that it is indeed such, nobody will deny who has been enabled, by comparative researches in the whole circumference of the elliptical valley, to prove that idea of its formation,—an idea indeed which immediately suggests itself to the observer from the elevated edge of the Val di Bove on the border of the Piano del Lago or Schiena dell'Asino.

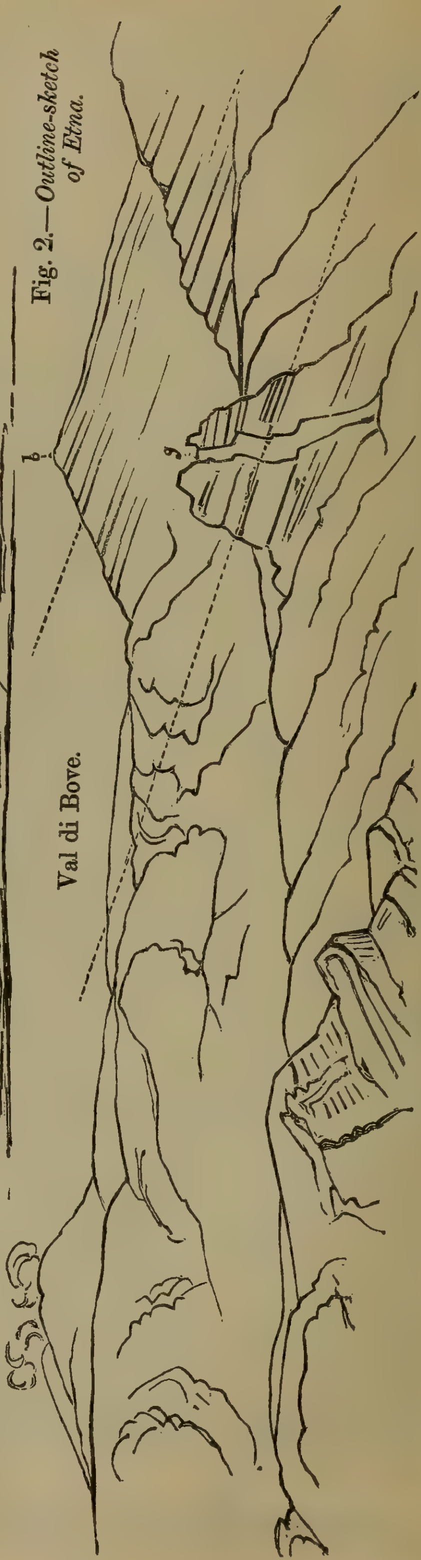
You are struck by some particulars in my figure of the mountain in Pl. 8 of my 'Views of Etna*,' and you desire to know how far those lines pointed out in your copy of it are based upon direct observation? In general, I have to confess that, when tracing those dotted lines, I may have forgotten that it was not the right place, in a profile constructed by hypsometrical measurements only, to hint at theoretical views, and that it would have been better to suppress not only the dotted line, but also those lines indicating a stratification, and intended to express a general law of structure applicable to the whole.

First, with regard to the *lines of stratification.* When opening my journal of those excursions on Etna, I have many proofs of my having seriously sought for a constancy in the dip of the planes of stratification in the central region of the mountain; but I found none. Such indications as appeared to be visible on the side of the Serra del Solfizio and the Rocca Giannicola seem to have only a local signification. At times I found the dip to be away from the valley; and at other places the dip was towards it. Independently of these anomalies, I could not but lay considerable importance on the general tendency amongst the upper beds in the central region of the Serra del Solfizio to horizontal stratification (fig. 4 *a*, *a′*, *b*), with an apparent slight dip towards the valley on one side, and the contrary on the other (fig. 6). I observed, too, that the dip in the Cisterna

* Erläuternde Abbildungen geologischen Erscheinungen beobachtet am Vesuv und Aetna in den Jahren 1833 und 1834, von Dr. H. Abich. 1837.

Fig. 1.—*Outline-sketch of Etna.*


Fig. 2.—*Outline-sketch of Etna.*




*b.* Cima; Punta Schiena dell' Asino. *g.* Rocca della Capre.

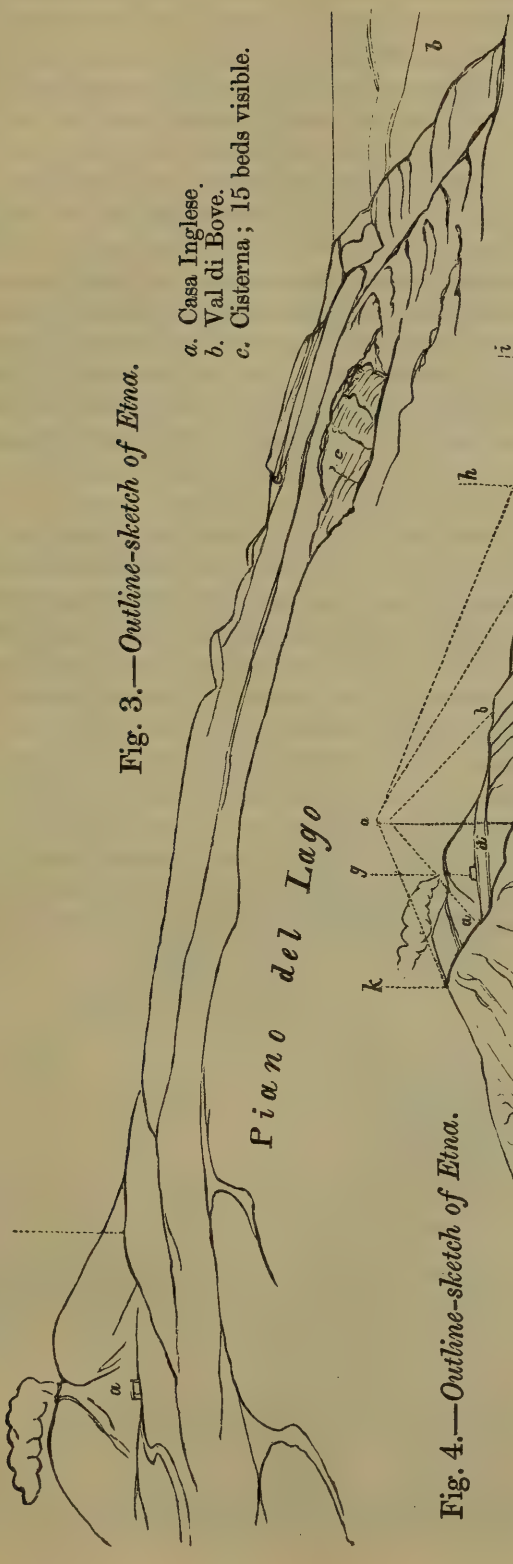



Fig. 3.—*Outline-sketch of Etna.*

*a.* Casa Inglese.
*b.* Val di Bove.
*c.* Cisterna; 15 beds visible.

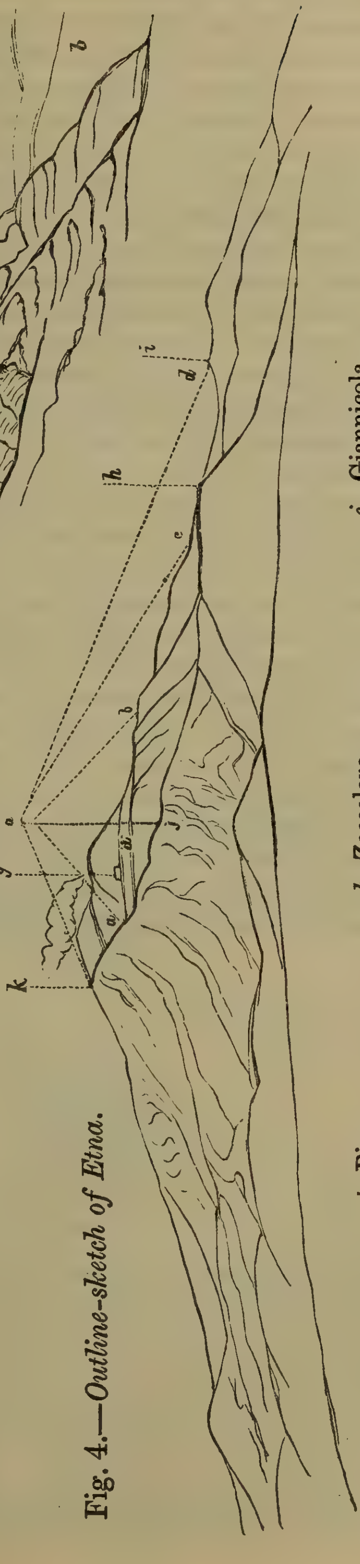


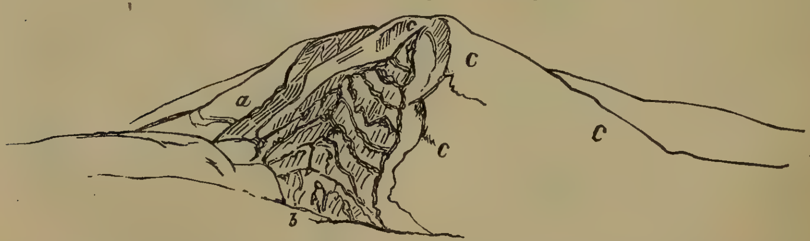
Fig. 4.—*Outline-sketch of Etna.*

*a'.* Piano.
*g.* Casa Inglese.
*h.* Zoccolaro.
*i.* Cima della Valle.
*j.* Giannicola.
*k.* Montagnuola.

(fig. 3) is somewhat towards the valley; but I believed it to be much more so on the north-western top of the steep border of the Val di Bove on the side of Schiena dell'Asino. I observe too that the dip of the beds of the said Schiena was at 16° to 20° towards the N.N.E., and prevailed throughout the whole ridge as far as the Cirrita. I saw the conformity of stratification away from the valley, with the same dip of the beds of Schiena dell'Asino, in the Rocca della Capre and Musarra (fig. 2); and all seemed to me, according to my theoretical view, quite right, when I found on the side of Zoccolaro, notwithstanding great irregularities, a mean inclination of all the beds towards south and south-east. According to my view I believe it impossible that the effect of a subsidence of so enormous extent as that corresponding to the circuit of the actual Val di Bove should have taken place without the greatest derangement, especially in the original structure of the central masses of the mountain (fig. 4 *b*, *c*, *d*), by a gliding towards the chasm in an altered position between *b* and *a*, fig. 1.

The considerable anomaly in the dip of beds away from the valley round or behind the Giannicola, I looked upon as a natural consequence of the protrusion of that gigantic dyke, or rather system of dykes, constituting the Solfizio and the Giannicola. When descending from the border of the Piano del Lago (fig. 4 *á*), and studying step by step the stratified masses, I was struck by the relation I saw between the beds (originally horizontal) dipping away from the valley and the protrusion of the immense dykes, the direction of which, as far as my examination could reach, was that of N.N.W.–S.S.E. This circumstance strengthened me in the opinion that this anomalous position of the beds ought to be a consequence of the protrusion of the dykes almost perpendicular to the chief direction or great axis of the elliptical chasm of the Val di Bove. When

Fig. 5.—*View of Montagnuola.*




*a*. "Lava tavolata" of the same mineralogical composition as those beds belonging to uppermost lava-currents of the Piano del Lago, the same which make their appearance in the interior of the Cisterella, where I observed 15 beds superposed one on the other.

*b*. Lava of the eruption of Montagnuola.

*c*. Cone of eruption; ejected cinders and capilli.

[*a* is to *c* as Somma (*cratère de soulèvement*) is to Vesuvius (*volcan*).]

studying the remarkable Montagnuola, on the southern extremity of that part of the edge of the valley which stretches from N. to S., I found the same beds of lava laid open to the sight in the interior of the neighbouring Cisterella. These beds rise in the vicinity of the Montagnuola, and suddenly appear lifted up in order to form the crater-like wall (fig. 5 *a*) which half surrounds the cone of the Montagnuola, comparable (geologically) to Somma with regard to Vesuvius, the central cone of eruption (*c*).

All those lava-currents which the subsidence of the Cisterella cut through, following the same inclination as the Piano del Lago in its beginning from the Torre del Filosofo to the Montagnuola, show a peculiar resemblance to the modern currents of Etna, partaking of the magnetic property in a very high degree. By this quality all those superior lavas of the Piano del Lago, as well as the upper beds of the Cima della Valle on the northern side, differ essentially from the older beds, of more trachytic composition, which form the veritable central body of the mountain. I may remark that I made a similar observation with regard to the very notable petrographical difference between the older rocks of Ararat and the black doleritic lavas covering the upper part of the burst mountain. I believe these physical differences of the rocks belonging to one and the same system to be in intimate dependence on a notable change in the mode of formation governing the whole system.

Fig. 6.—*Beds and Dykes on the slope between Giannicola and Musarra.*

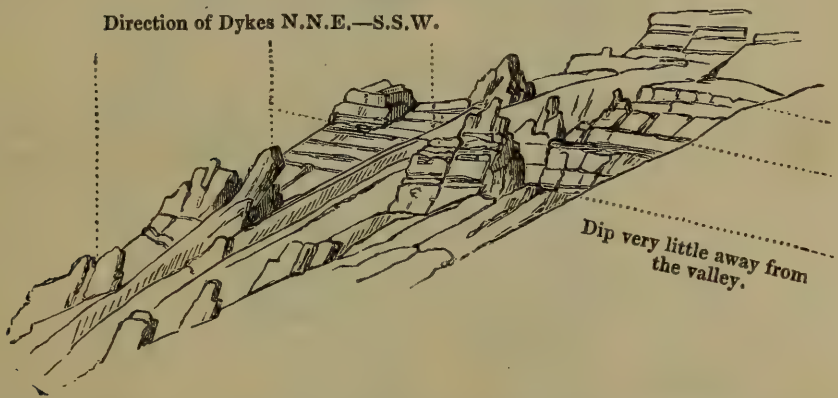
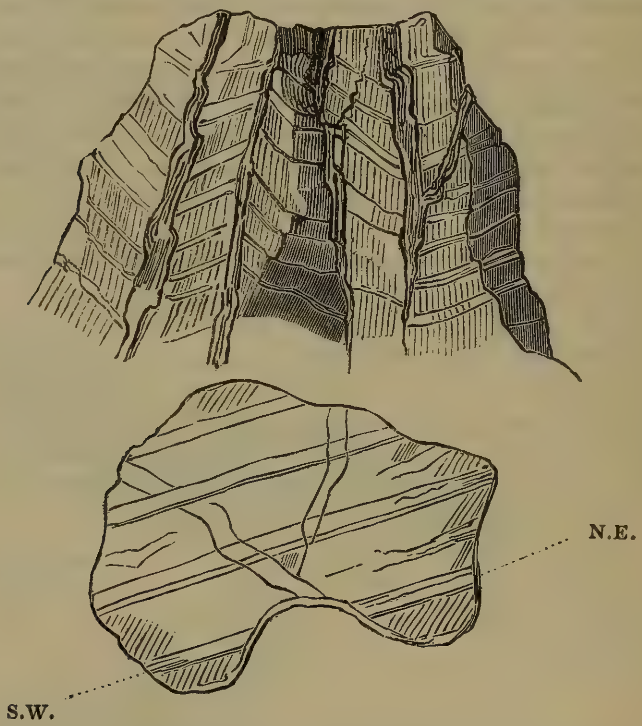



Fig. 6 gives an exact representation of what I saw higher up than the great masses of the Giannicola or Musarra, illustrating the almost horizontal position of the slightly curved beds, intersected by dykes running in the above-mentioned direction of N.N.E.–S.S.W. It must not be forgotten that this part of the slope corresponds to the *middle* region of the interior body of the mountain (fig. 4 *a*, *b*, and fig. 1 *a*), and that, in my opinion, both to the left and right of those regions, the effect of original subsidence was still sensible enough to prescribe the way that all the future currents of doleritic lava, poured out from the modern excentric volcano, should take down to the valley. Putting aside my belief of the probability of all those beds on the upper region of the western border of Val di Bove, and dipping towards the latter, belonging to quite a different order of things, in the history of the mountain, to those dipping away from the valley, you will find it excusable that I had adopted in my section of Etna (Pl. 9) the disposition of the stratified masses according to fig. 6. To make my views clearer as to the dipping of the tuff-agglomerate and lava away from the valley at the Rocca Giannicola, where these rocks occur distinctly stratified, and inclined at angles varying from 20° to 30° to the N. and N.W., I will add a few words on an interesting phænomenon observed by me at the Rocca della Capre. A copy of my sketch, made on the spot, is added here (fig. 7). You have probably observed the same fact; and you

Fig. 7.—*Dykes on the Rocca della Capre. Facing towards N.E.*




will see whether I agree with your opinion about it or not. Everybody who examines the Rocca della Capre will agree with me that it is to be considered as a remnant of the great formation of alternating beds of crystalline trachytic rocks and tufa, which subsided in consequence of the catastrophe that ultimately brought Etna to its present shape. Notwithstanding the regularity which shows the dip of the beds (as also the mean direction of the traversing basaltic dykes, from N.E.–S.W.) to be the same prevailing in the beds of the Cima (fig. 2), that is, away from the valley towards the north, there is a considerable bending by zigzag inclinations of the beds in the Rocca della Capre, which seems to be a consequence of the close grouping of dykes, favoured by local circumstances. This we must suppose to be the fact; otherwise the phenomenon ought to be very

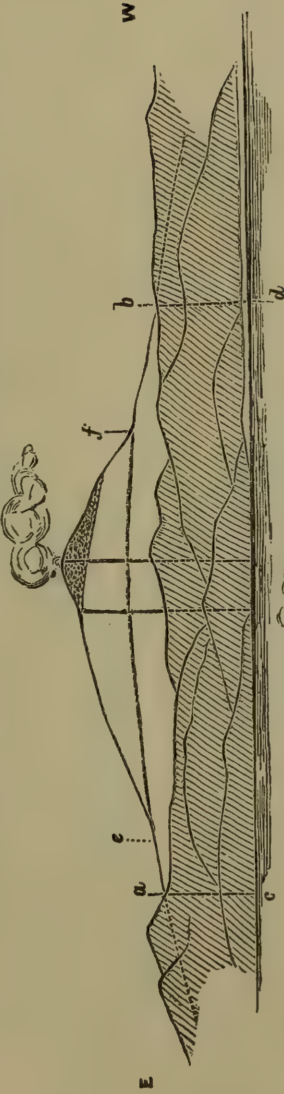



Fig. 8.—*View of Sicily, Etna in the distance, from the Sea between Messina and Tropea.*


Fig. 9.—*View of Etna, taken between Sta. Catarina and Villarosa.*

*g.* Val di Bove. *h.* Castragiovanni. *i.* Valley of the Simeto.

frequent in the walls of the Val di Bove. Applying this observation to the gigantic group of dykes concentrated in the huge masses of Rocca Giannicola and Musarra, I think that we must not give too great a value to the dip of the beds of tufa and the crystalline layers of the older formation of Etna in the immediate neighbourhood of the said Rocca, St. Nuolo, and Musarra.

I have still to say some words about the dotted line and the theoretical view which it points out. The first time I approached Mount Etna (it was on the road from Palermo to Catania, some hours before the moment I escaped with my life from the murderous hands of robbers, who killed my poor guide instead of myself), I admired for a long time the beautiful and regular shape of the chief body of the mountain, which presented itself, at the distance of about 40 Italian miles, as a flattened dome with a base "doucement bombé;" and the vertex corresponded, in the midst of the smoking summit-cone, exactly to that point from whence a perpendicular reached the centre of the imaginary circle, the segment of which was projected before my eyes, as by the dotted line of fig. 9 (*a*, *b*). Coming in a straight line from west to east, I saw the mountain in the exact extension of south to north. On my return from Sicily to Naples, Etna presented itself with admirable clearness at a somewhat greater distance from the sea in a direction of about S. 25° W. Fig. 8 gives a copy of this view, which I made with as much exactness as I could, by taking the chief angles by means of my pocket-sextant. The shape of the mountain corresponds here exactly to a natural profile obtained by cutting the mountain in the direction of N.W.–S.E., namely the mean direction of the longitudinal axis of the Val di Bove. You will remark here the coincidence in the nature of both curves (*a b*, fig. 8, and *a b*, fig. 9), which is best perceivable by the equal abscisses *a c* and *b d*, at equal distances from the central vertical line passing through the top of the under cone. Seek now the centre of that second superior circle which circumscribes the contour of the dome-shaped upper half of the mountain in the view fig. 8; you will see that its position does not exactly coincide with the former, but it lies a little more to the east.

Suppose that upper portion which is dotted to be absent, and you get the old Etna as it probably was before the establishment of the modern cone in that second period when the volcanic outbursts from eruptive fissures became concentrated into one single vent, by which the communication between the atmosphere and the volcanic focus continued now to take place only. Our late excellent mutual friend, Gemmellaro, at Nicolosi,—the first who pointed out the interesting fact of the excentrical position of the actual modern cone of Etna with all its dependencies (with regard to the central axis of the older Etna),—certainly never had an idea of the acuteness and subtility by which this geological manner of viewing it is justified by projections of the general shape of that mountain, taken at considerable distances round the cardinal points of the horizon and compared together.

Thus supplying the profiles fig. 8 and fig. 9, I give in fig. 10

a copy of the view of Etna taken by me from the hillock near Paterno, on the left side of the valley of the Simeto. It shows Etna from the southern side, exhibiting the outlines of a profile to be obtained by a section through the mountain in the direction of the longitudinal axis of the Val di Bove. Although this view, taken from the very base of Etna, does not give a commanding view so complete and so free from the influence of perspective as the views fig. 8 and fig. 9, it is not difficult to recognize the original flattened cone, the "terrain bombé" of *ab*, fig. 8, as well as the dome-shaped part of the mountain between *e* and *f* of fig. 8. The gibbosity arising from the modern lava-formation after the "soulèvement" of Etna (the same indicated by the dotted portion in fig. 8) appears here more evident than in the figure referred to, because it was from the western side, in the direction of Bronte, that the eruptive materials have found, very often and on a large scale, their way from the top of the mountain, producing a sensible local increase of masses on that side of the slope which in the view fig. 10 is marked *a*. It is an effect similar to that produced by eruptive forces only, which I tried to illustrate by the woodcut accompanying my paper "on the changes which the cone of Vesuvius has undergone within the last nineteen years." The view in fig. 10 is of peculiar interest, as it shows the basaltic beds (lava) of Aderno and Paterno (*b*) in their immediate superposition upon the clastic and argillaceous beds of the same regenerated rocks of secondary age, as those make their appearance on the right hand of the Simeto, and are supposed to stretch far in a northern direction under the base of the older volcanic formation of Etna.

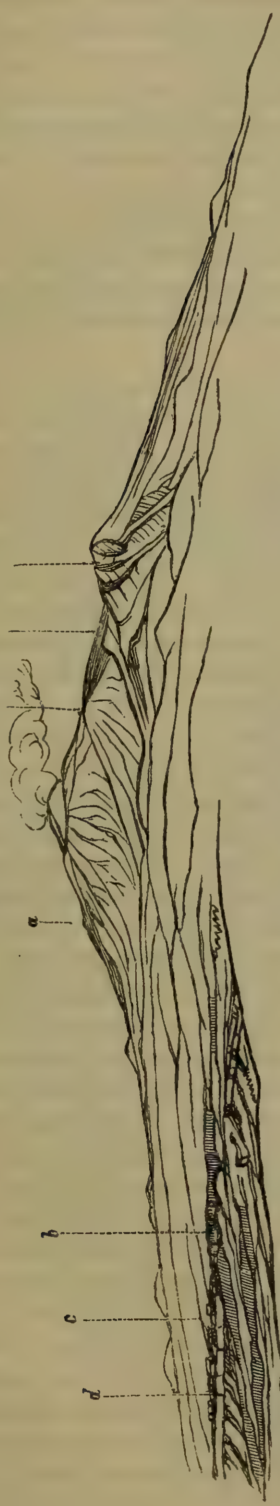



Fig. 10.—*View of Etna, taken from the Hill of Paterno.*

*b.* Modern lava near Aderno. *d.* Sandstone-gravel, clay, &c. *f.* Val di Bove.
*c.* Older basalt. *e.* Monte Frumento. *g.* Montagnuola.

It is a fact of importance, that both the basaltic hillocks of Paterno and of Motta Sta. Anastatia, as well as those of Aci Reale and Trezza near Castello di Aci, show the geological character of basaltic dykes (accompanied near Paterno by a tufaceous conglomerate composed of much altered fragments of secondary rocks). The direction of all those cliff-like outbreaks of basaltic rocks is perfectly the same as that of the dykes of the Rocca, Giannicola, Musarra, &c. in the Val di Bove, and coincides, too, with the direction of that remarkable fissure which runs from the crater of Etna to the Torre del Filosofo, and further on to the Cisterna.

The fact of the frequent return of that remarkable direction, S.S.W.–N.N.E., in so many dykes at the southern base of Etna, and in the interior of the Val di Bove, may be supported here by an example which, moreover, presents a geological accident of high theoretical interest.

In order to bring what I am about to say on the fact represented by fig. 11 (p. 127) in connexion with that class of phænomena of which it forms an excellent example, we will start from the foot of the lateral cone on the border of the Piano del Lago, the "Montagnuola," in a south-eastern direction, with the intention of examining the nature of the upper beds forming the sharp crest of the deeply fractured southern wall of the Val di Bove. The lava of the Montagnuola is distinguished by the basalt-like black colour, as also by the presence of olivine, labradorite, and augite in the interior of the mass. Excepting this, it is very difficult to point out a good character of difference between the rocks forming the beds of older origin (of Etna) and those which broke out after the catastrophe of the subsidence in which originated the Val di Bove. All the lava-beds of the Piano del Lago have an equally strong action upon the magnetic needle, when they are examined in the interior of the Cisterna or Cisterella, as well as at the border of the Piano. The resemblance to the modern lava is in general a striking quality of the uppermost beds of the elevated walls surrounding the elliptical chasm of the Val di Bove. There seems to be an insensible passage from the doleritic character of those upper beds into a more trachytic one on the deeper-lying beds. Nevertheless the great confusion and intersections which prevail among the projecting beds along the border of the valley, in consequence of subsidences, reiterated eruptions, and atmospheric agencies, make it a matter of great difficulty to study such mineralogical passages step by step. The extraordinary variety of felspathic lavas belonging to the trachy-dolerites, in which pyroxene often makes its appearance, coincides with the same variety in the numberless dykes by which the former are intersected. Amongst those dykes I observed one in the usual form of an almost perpendicular wall, trending exactly N.N.E. and S.S.W. It is of no considerable height, but of great length. It was a very compact, fine-grained, and pale-grey greystone of phonolitic appearance, sonorous, and several feet in diameter. In the middle this dyke is split into numberless plates, like slate of the finest quality, rising up perpendicularly. These central slates are very friable and sound like glass. Towards the outer sides of the dyke the grey homogeneous slaty mass becomes more coherent, and passes into a black pitchstone-like crust, which covers the sides of the dyke with a regular layer of a more or less glassy substance, some inches thick, and as black as coal. On the outside of the dyke the black glassy crust showed on its uneven surface, and imbedded in it as in a paste, a great quantity of small and great fragments of the rocks composing the horizontal beds through which the dyke had passed. The magnetic power of this dyke was considerable. Advancing still more along the crest of Monte Zoccolaro, and bending a little on a more gentle slope of a detached part of that enormous ridge towards the valley, I was struck by the curious phænomenon of which fig. 11 gives a very

Fig. 11.—*Grotta del Subi Legno, on the side of Monte Zoccolaro.*

true representation. A dyke of a mean diameter of 6 feet, consisting of a compact felspathic lava, and trending N. 35° W., suddenly stops the path. The surface of the outside is scorified, exhibiting a smoothly rounded kidney-shaped crust. When turning round that curious massive wall, which terminates at the crest in a kind of pad, overhanging a little towards the south-eastern side, I perceived that there was an immediate passage from the mass of the perpendicular dyke into a regular layer or bed of the same stone towards the eastern side. This layer, from its beginning at the top of the dyke, went down with a mean inclination of 25°, and regained an almost horizontal position from 6° to 0. The masses which once fitted the corner between the dyke and its detached layer are partly removed, having given way to a great extent by lateral subsidence. The cavern thus formed is somewhat spacious and has the name of "Grotta del Subi Legno;" the physical nature of the roof of this cavern is that of a half-smolten scorified lava; great stalactites in huge masses, hanging down from the roof, correspond to former depressions in those fragmentary layers over which the lava, pouring out of its perpendicular channel, had first to flow. That lava-stream shows how lava-currents—suppose they are given out by rents of considerable length—are capable of forming regular layers, of even 25° inclination, without the slightest difference in the internal structure of the rock both of the dyke and of the layer. On its outer surface this lava-bed shows the same scorified appearance as on the surface visible in the interior of the cavern.

The nature of the mass which forms the dyke shows some interesting peculiarities. The rock is compact and highly crystalline. In the axial region a spongy zone of pores of considerable size runs upwards; these pores are hollow, and of the same appearance as the ordinary pores of recent lava. The most compact mass is near the sides of the dyke. Towards the interior of the dyke, this compact crust is lined by a small zone, finely porous, which soon gives place to the homogeneous central stone, quite free from pores, excepting in the before-said highly porous zone in the axis. The magnetic power of this dyke is extraordinary; the needle, when approached, turns immediately at a right angle to the surface of the dyke's sides.

The importance of this phænomenon on this part of the mountain as respects the history of Mount Etna, is obvious. There cannot be any doubt that the outburst of this eruptive matter, becoming immediately a lava-current on that side where the inclination of the soil favoured its descent, took place when the whole system of those alternating layers of tufa, conglomerates, and lava, now called Etna, which the dyke has cut through, existed almost in its actual position. The considerable extension of the bed in fig. 11 throws much light on the manner by which a great part, perhaps the greatest part, of what we have called the older Etna may have been built up by successive eruptions out of longitudinal vents, under the synchronous influence of a gradual slow upheaving of the whole system. The direction N.N.W. and S.S.E. is the prevailing one with the dykes round Etna, as well as in the interior of the Val di Bove. But it is remarkable that this direction is also the parallel of the longitudinal axis of the older Etna (figs. 8 and 9, *a*, *b*), such as the mountain was before the catastrophe which was followed by the subsidence of what we now call the "Val di Bove." The most modern consequence of this direction, by which, in the earliest period of the volcanic eruptions, were traced the first lines of what became so immense a construction in our modern epoch of lava-formation, is the rent across the Piano del Lago on the top of the old Mount Etna!

But I believe it is now time to return from this long excursion round Etna, to which I felt myself irresistibly invited by your questions. My election, too, as a Member of the London Geological Society incited me, and most agreeably too, to prove to you, by this communication, and to the Society also, how much I feel myself honoured by the honorary title of Foreign Member lately given me.

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2. *On the* LACUSTRINE *or* KAREWAH DEPOSITS *of* KASHMIR. By H. H. GODWIN-AUSTEN, Lieut. H.M. 24th Regt., Kashmir Survey.

[The publication of this paper is unavoidably postponed.]

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3. *On the* Black Mica *of the* Granite *of* Leinster *and* Donegal; *and its probable identity with* Lepidomelane. By the Rev. Samuel Haughton, F.R.S., F.G.S., Fellow of Trinity College, Dublin, and Professor of Geology in the University of Dublin.

We owe our knowledge of Lepidomelane to a single analysis, made by Soltmann, of a specimen from Petersberg, Wermland. He describes it as occurring in an aggregate of minute black scales, in small six-sided tables, with perfect basal cleavage—either hexagonal or trimetric, easily dissolved in muriatic or nitric acid, leaving a skeleton of silica.

Its composition is as follows—

*Lepidomelane.*

| | Per centage. | | Atoms. | | |
|---|---|---|---|---|---|
| Silica | 37·40 | .. | | 0·831 | 3 |
| Alumina | 11·60 | .. | 0·223 | 0·569 | 2 |
| Peroxide of Iron | 27·66 | .. | 0·346 | | |
| Protoxide of Iron | 12·43 | .. | 0·345 | 0·551 | 2 |
| Lime and Magnesia | 0·26 | .. | 0·010 | | |
| Potash | 9·20 | .. | 0·196 | | |
| Water | 0·60 | | | | |
| | 99·15 | | | | |

This analysis gives very nearly, in atoms—

| | | | | |
|---|---|---|---|---|
| $SiO_3$ | .... | 3 | .... | 9 |
| $R_2O_3$ | .... | 2 | .... | 6 |
| RO | .... | 2 | .. | 6 |

Soltmann does not appear to have ascertained whether his mica were uniaxal or biaxal, as he is in doubt whether it is trimetric or hexagonal.

In my first paper* on the Granites of Leinster, I have mentioned the black mica which is found accompanying the white margarodite of the Leinster granite, in small flakes, and noticed the curious fact that these flakes are sometimes physically imbedded in the plates of white mica, without injuring their fissility or lustre, but always effecting a reduction of about 20° in the angle between the optic axes of the latter.

Since the publication of that paper, I have ascertained the existence, in large quantities, of a similar black mica in the Co. Donegal, both in granite and gneiss; and also, through the kindness of Mr. Cotton, C.E., obtained specimens of the black mica of the Leinster granite, found in large crystals in the cuttings of the Bagenalstown and Wexford Railway, at Ballyellin, in the Co. Carlow.

The black mica of Ballyellin is found in crystalline plates, 2 in. by ½ in.; it is not only associated with, but physically united to, the

* Quart. Journ. Geol. Soc., vol. xii. p. 175.

white margarodite mica of the same locality,—plates of the white mica being frequently met with containing large crystals of the black mica, imbedded without any breach of continuity—and *vice versâ*. The angles of the crystalline plates of black mica are all 120°; and, on examination by polarized light, it turned out to be uniaxal. I examined with care the optical condition of the plates of white mica which are continuous with the plates of black uniaxal mica, and found that the plane of the optic axes of the white mica was perpendicular to the common surface of the black and white micas, and always contained the bounding line between the two minerals.

I found the angle between the optic axes of the white mica to range, in different specimens, from 56° 30′ to 71°.

The black and white micas of Ballyellin occur in a coarse granite, of which the other constituents are grey quartz and white orthoclase in large crystals.

In the neighbourhood of Ballyellin, at Scalloge Gap, between Mount Leinster and Blackstairs, the black mica occurs in nests and lenticular sheets, in a fine-grained granite, composed of white mica, white felspar, and grey quartz.

The following is the composition of the

*Black Mica of Ballyellin.*

| | Per centage. | Atoms. | |
|---|---|---|---|
| Silica | 35·55 | | 0·790 |
| Alumina | 17·08 | 0·328 | 0·624 |
| Peroxide of Iron | 23·70 | 0·296 | |
| Lime | 0·61 | 0·021 | 0·538 |
| Magnesia | 3·07 | 0·153 | |
| Soda | 0·35 | 0·011 | |
| Potash | 9·45 | 0·201 | |
| Protoxide of Iron | 3·55 | 0·098 | |
| Protoxide of Manganese | 1·95 | 0·054 | |
| Loss by ignition | 4·30 | | 0·477 |
| | 99·61 | | |

Ten grains of the mineral, acted on with muriatic acid, were found to be completely decomposed, giving 3·52 grs. of slightly gelatinized silex, much of which retained the skeleton form of the mica.

The result of the foregoing analysis, in atoms, is very accurately

$SiO_3$ ............ 9,
$R_2O_3$ ............ 7,
$RO$ ............ 6,

differing from Soltmann's result by the addition of one atom to the peroxides. If we compare directly the total quantity of oxygen in all the bases with the oxygen of the silica, we see that they are exactly equal; so that the formula of this mica may be thus written:

$$[\tfrac{2}{9}(3RO)+\tfrac{7}{9}R_2O_3]\,SiO_3;$$

Or, as I would prefer stating it—

$$[23(3RO)+77\,R_2O_3]+100\,SiO_3.$$

Soltmann's lepidomelane, written in the same way, gives us, either

$$[\tfrac{1}{4}(3RO)+\tfrac{3}{4}R_2O_3]\,SiO_3^{\frac{9}{8}};$$

or,

$$[25(3RO)+75\,R_2O_3]+110\,SiO_3.$$

A black mica, similar to that of Ballyellin, Co. Carlow, occurs in the Poison Glen, leading to the Pass of Ballygihen, in the Co. Donegal. It is uniaxal and soluble in muriatic acid. It occurs in granite, in $\frac{1}{2}$-inch plates, accumulated, at times, to $\frac{1}{4}$-inch thickness. The following is its analysis.

*Black Mica of Ballygihen.*

| | Per centage. | | Atoms. | |
|---|---|---|---|---|
| Silica | 36·20 | .. | | 0·804 |
| Alumina | 15·95 | .. | 0·307 | } 0·647 |
| Peroxide of Iron | 27·19 | .. | 0·340 | |
| Lime | 0·50 | .. | 0·018 | } 0·515 |
| Magnesia | 5·00 | .. | 0·250 | |
| Soda | 0·16 | .. | 0·005 | |
| Potash | 8·65 | .. | 0·184 | |
| Protoxide of Iron | 0·64 | .. | 0·017 | |
| Protoxide of Manganese | 1·50 | .. | 0·041 | |
| Loss by ignition | 3·90 | .. | | 0·433 |
| | 99·69 | | | |

If the result of this analysis be written as the former one, we obtain for its formula

$$[21(3RO)+79\,R_2O_3]+98\,SiO_3.$$

If written according to Dana's method, this would be

$$[\tfrac{1}{5}(3RO)+\tfrac{4}{5}R_2O_3]\,SiO_3.$$

The black mica of Donegal is certainly identical with the black mica of Carlow and Leinster, and probably the same as the black mica described as "lepidomelane" by Soltmann. In the Ballygihen district, after passing the Gap, the mica of the granite becomes white mica, biaxal, in large plates, with angles between the axes ranging from 62° 10′ to 65° 10′. It is not associated with the black mica, however, as is the case in the Leinster granites.

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## 4. *On an* Outlier *of* Lias *in* Aberdeenshire. By T. F. Jamieson, Esq.

(In a Letter to Sir Roderick I. Murchison, V.P.G.S., &c.*)

In a cutting of the Banff, Macduff, and Turriff Extension Railway, about four miles to the north of the latter town, close beside the turnpike-road at the Plaidy toll-bar, there has been exposed a mass of a very tenacious clay, blue in colour, and of homogeneous texture, which contains many *Ammonites*, *Belemnites*, and other fossils characteristic of the Lias, such as *Gryphæa*, *Plagiostoma*, and possibly others;

* Dated Ellon, Aberdeenshire, March 17, 1858.

these I have got myself. I also saw in the possession of one of the "navvies" a fragment of a shell resembling a *Nerinæa*, in remarkably fine preservation.

The altitude of the railway-cutting above the level of the sea, as I learn from the engineer on the line, is 250 feet. At the time of my visit the excavation had reached a depth of from 10 to 15 feet, and the "navvies" were busy at work in the "gullet," filling their waggons with the clay, which is a mass of a fine greenish-blue colour, very compact and tenacious, and unlike any other clay in this part of the country. It consists of a fine impalpable mud, devoid of all manner of stones or pebbles, save occasionally a hard greenish nodule, enclosing the remains of a large Ammonite.

This clay is covered by a stratum of the Pleistocene Drift, of a brownish-grey colour, very sandy in some places, and of a more clayey nature in others. In this drift I found many striated fragments of clay-slate, together with bits of other primary rocks. The line of junction between the two beds is very undulating and irregular; in some places the Lias-clay reaches nearly the surface of the ground with a well-defined outline; while in others it is covered by several feet of the drift, which, towards the southern end of the cutting, appears to occupy almost the whole of the excavation, the Lias being wasted almost wholly away, and imparting in some places to the overlying mass a dark-bluish hue, and a more clayey nature, so that the line of junction becomes less defined. The bottom of the Lias-clay had not been reached, so that I did not see what it rests upon; but the old clay-slate comes to the surface within a stone's throw of the spot, and is found in the neighbourhood all around; so that we have here but a small remnant—the merest patch—left of this interesting deposit.

The most abundant fossil is the Ammonite, of all sizes, from individuals of a quarter of an inch in diameter to five inches. The nacreous lustre of these shells—especially in the smaller and more delicate specimens—is generally in beautiful preservation. These Ammonites were most plentiful at the north end of the section, where the cutting was commenced. In some places every spadeful contained dozens of delicate thin-shelled Ammonites, much decayed, but still preserving their rainbow-like lustre. Owing to the progress of the work, and the sloping of the sides, they are now more difficult to be obtained. Next to these, the most common organism is a large bivalve like a *Lima*, measuring 4 inches in the longest direction, by $3\frac{1}{2}$ inches across. Part of the brown-coloured shell remains in complete preservation; and both valves are in conjunction and shut, the interior being filled with a greenish-coloured mass of the same appearance as the surrounding clay, but of a more stony texture.

The clay in some places contained the decayed remains and impressions of many smaller shells, from 1 inch to $1\frac{1}{2}$ inch in size, and having the characters of *Lima*.

Broken pieces of *Belemnites* are also not very unfrequent; also specimens of a *Gryphæa*, measuring 5 inches in diameter, resembling *G. incurva*. Among some specimens, which I owe to the kindness of my friend Mr. Alex. Murray, of Nethermill, there are other shells of a smaller size, and of a form somewhat resembling a *Mya*.

A proof that this is no bed of Pliocene clay, and that the fossils have not been drifted, lies in the fact that these shells, especially the smaller ones, occur in groups,—the little *Ammonites* being congregated together, and the *Limæ* huddled in clusters by themselves.

The occurrence of this relic of the Lias is of considerable interest, as it throws light upon the source of the Liassic fossils, whole and in fragments, which are met with in the Drift of the valley of the Deveron and of other parts of Aberdeenshire, even towards its eastern coast: it also points to an extension of the sea of the Lias period into quarters not previously imagined; and, connected with the Chalk-flints and fragments of Greensand found in this county*, it strengthens the supposition that these also are native to the district where we now find them, and not transported from afar, as some have thought.

I informed Prof. Nicol of the results of my examination of this spot a short time ago; and he, in reply, told me that one of his pupils had brought him some of the fossils of this clay, and that he had seen others in the possession of some individuals at Aberdeen. I am not aware, however, whether any experienced geologist has personally examined the locality.

I am not aware of the Lias or Oolite having been found in this county previously, nor anywhere else so far east, or perhaps so far inland, in Scotland.

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## 5. *On some* Outline-drawings *and* Photographs *of the* Skull *of the* Zygomaturus trilobus, *Macleay* (Nototherium, *Owen?*). By Professor Owen, F.R.S., F.G.S., &c.

[See further on, p. 168.]

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## 6. *On the Occurrence of some* Tertiary Fossils *at* Grove Ferry, *near* Canterbury, Kent. By John Brown, Esq., F.G.S. *With* Descriptions *of some of the* Species; by G. B. Sowerby, Esq., F.L.S.

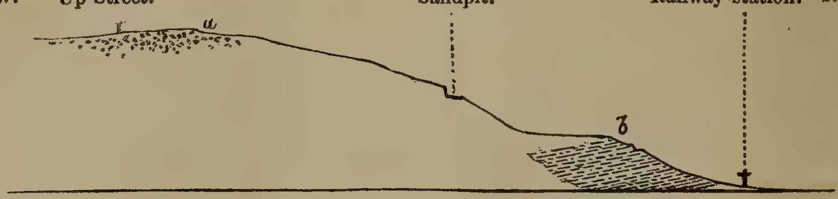
[Plate V.]

My friend Mr. Prestwich having kindly informed me of an interesting fossiliferous deposit at Wear Farm†, in the parish of Chislet, I was endeavouring to find the spot in 1854, when accidentally I heard of a little sand-pit in a garden near Grove Ferry, also in the parish of Chislet (about a mile and a half from Wear Farm), on the left-hand side of a lane leading from the railway-station to the little village of Up Street, nearly a mile from the village of Chislet. Up Street is on the high road from Canterbury to Ramsgate, and six miles from the former. The pit was rather more than halfway up the side of the hill, and within about thirty feet of its top. The

* See Quart. Journ. Geol. Soc. vol. xiii. p. 83.

† See Mr. Prestwich's paper on these gravels and sands, Quart. Journ. Geol. Soc. vol. xi. p. 110.

surface of the ground slopes down to the River Stour. Gravel caps the hill; and the Lower Tertiary sands are seen in a section, at its foot, near the railway-station, and also at a farm about half a mile to the east.




*a.* Gravel. *b.* Thanet Sands.

The fossil shells which I found in the little sand-pit were mostly very fragile, but in considerable abundance. They occurred both in sand and in dark red clay §; and some were nearly white, whilst others were tinted rusty red. Those which belong to Crag species appeared especially to be of a reddish colour.

The beds forming the central portion of this hill above Grove Ferry would appear, according to Mr. Prestwich's sections ¶ of the Lower Tertiaries of that neighbourhood, to belong to the "Basement-bed of the London Clay," overlying "Woolwich beds" and "Thanet Sands;" but many of the fossils which I collected here in 1854, and at subsequent visits, appear to have an Upper Tertiary character; indeed some cannot be distinguished from Crag species. Others, on the contrary, resemble forms belonging to the Middle and Lower Tertiary deposits.

The following list of the species collected by me in 1854-57 has been drawn up by Mr. George B. Sowerby.

### *Fossils from Up Street near Chislet.*

The New Species are marked thus *; the Crag species, †; the Lower Tertiary species, ‡; and the Belgian Tertiary species, ||.

*Cirripedia*:—

† 1. Pyrgoma anglica, *Sow.* Gen. of Shells.
* 2. Balanus Chisletianus, *G. B. S.* Pl. V. fig. 7.

*Mollusca Acephala*:—

3. Mactra; a fragment. (=M. ovalis, *Sow.* M. C. pl. 160?)
‡ 4. Corbula Regulbiensis, *Morris*, Q. J. G. S. x. pl. 2. f. 4–6. (Woolwich beds.)
|| 5. ——— Hencklinsiana, *Nyst*, Coq. Foss. Belg. p. 63, pl. 2. f. 3.
† 6. Nucula tenuis, *Montagu*; Wood, Monog. pl. 10. f. 5.
† 7. ——— nucleus, *Linn.*; Wood, Monog. pl. 10. f. 6.
‡ 8. Pectunculus Plumsteadianus, *Sow.* M. C. pl. 27. f. 3. (Woolwich beds.)
† 9. Limopsis aurita, *Wood*, Monog. pl. 9. f. 2. Pl. V. fig. 4.
10. Lucina? (fragmentary).
‡ 11. Cyprina Morrisii, *Sow.* M. C. pl. 620. (Thanet Sands.)
* 12. Astarte elevata, *G. B. S.* Pl. V. fig. 6.
† 13. ——— gracilis, *Goldf.*, var. multilineata, *Wood*, Monog. pl. 17. f. 3.
† 14. ——— Burtinii, *Lajonk.*; Wood, Monog. pl. 17. f. 5.

§ I found three specimens of *Limopsis aurita* in the clay; *Purpura vulgaris* occurred in the sand.

¶ Quart. Journ. Geol. Soc. vol. viii. pl. 15.

† 15. Cyrena consobrina, *Caill.*; Wood, Monog. pl. 11. f. 15.
‡ 16. Cardium Laytoni, *Morris*, Q. J. G. S. x. pl. 2. f. 1, 2. (Woolwich beds.)

*Mollusca Gasteropoda*:—

‡ 17. Rostellaria Sowerbyi, *Mantell*; Sow. M. C. pl. 349. f. 1. (London Clay.)
‡ 18. Trophon subnodosum, *Morris*, Q. J. G. S. viii. pl. 16. f. 10. (Thanet Sands.)
19. Pleurotoma; imperfect (=P. acuminata?, *Sow.* M. C. pl. 146. f. 4).
* 20. Pyrula nodulifera, *G. B. S.* Pl. V. fig. 2.
† 21. Purpura tetragona, *Sow.*, var. vulgaris, *Wood*, Monog. pl. 4. f. 7.
† 22. Clavatula brachyostoma?, *Wood*, Monog. pl. 7. f. 8.
* 23. Buccinum concinnum, *G. B. S.* Pl. V. fig. 1.
† 24. Chemnitzia elegantissima, *Montagu*; Wood, Monog. pl. 10. f. 6.
25. Odostomia; like O. plicata, *Montagu*; Wood, Monog. pl. 9. f. 3, but without teeth on the inside of the inner lip.
† 26. Nassa reticosa, *Sow.*, var. costata, *Wood*, Monog. pl. 3. f. 10.
‡ 27. Natica Hantoniensis? *Sow.* [as figured by Nyst, Coq. Foss. Belg. pl. 39. f. 2.] (Barton and London Clays.)
† 28. ——— catenoides?, *Wood*, Monog. pl. 16. f. 10 *a*, *b*. (= N. glaucinoides, *Sow.* M. C. pl. 479. f. 4.)
† 29. Bulla concinna?, *Wood*, Monog. pl. 21. f. 6.
‖ 30. —— utricula, *Nyst*, Coq. Foss. Belg. pl. 39. f. 9.
31. Dentalium; probably new. Pl. V. fig. 5. Resembling one figured in Mr. Prestwich's paper on the Thanet Sands, Quart. Journ. Geol. Soc. vol. viii. p. 267. pl. 16. f. 12.
32. Helix; adhering to a broken *Fusus*.
33. Ringicula.
† 34. Valvata piscinalis, *Müller*; Wood, Monog. pl. 12. f. 3; in sand within a *Cardium Laytoni*.
35. Limax; shell smoother than in the common English species. Pl. V. fig. 3.

*Foraminifera*:—

‡ 36. Cristellaria platypleura, *Jones*, Quart. Journ. Geol. Soc. vol. viii. p. 267. pl. 16. f. 12 (=C. Calcar, *Linn.*).
Small Bones and Teeth of Fish, in abundance§.

Thus of 36 species, 14 are found also in the Crag of Suffolk; 8 have been described from the Lower Tertiaries of England; 2 have been hitherto known only in the Tertiaries of Belgium; 4 are new; and 8 are not determinable. I must here observe that my friend Mr. Prestwich¶, who has so long and ardently studied the Tertiary formations, especially of this district, and who has seen the fossils here referred to, does not concur with me in thinking that they belong to a bed of Upper Tertiary (Crag) age *in situ*. But whatever be the exact relations of these sands and clays found in the little sand-pit to be so full of the fossils above mentioned, I believe that this brief notice will be of service by directing attention to this interesting point, and lead others to clear up all doubts by a still closer examination of the spot.

§ These have unfortunately been mislaid.
¶ Mr. Prestwich, who has visited the pit, informs me that he considers that the section is made in a bed of sand lying just under the London Clay, he having found only a few shells, and those all of Lower Tertiary species.—J. B. Jan. 1859.

## *Description of some new* Fossil Species *collected by* John Brown, Esq., F.G.S., *at* Grove Ferry, Kent. By G. B. Sowerby, Esq., F.L.S.

Balanus Chisletianus, G. B. Sowerby. Pl. V. fig. 7.

*B.* subcylindricus, lævigatus, orificio dentato, mediocri; parietibus leviter fasciatis; radiis angustis; scuto lævigato cristâ articulari elongatâ validè reflexâ; tergo obtuso, calcari acuminato elongato.

The slope of the radii gives to the orifice a dentated character which brings our species near to *B. concavus*; but the scutal valves of the operculum are without longitudinal striæ, and their articular ridge is long. Also the spur of the terga is oblique, produced, and pointed.

Astarte elevata, G. B. Sowerby. Pl. V. fig. 6.

*A.* testâ trigonâ, altâ, posticè truncatâ subangulatâ, ad marginem ventralem lævi, medio leviter liris undulatâ; apice elevato liris rotundis crebris rugato.

This shell differs from *A. rugata* of the 'Mineral Conchology,' and from *A. Omalii*, Lajonk. (Nyst), in being much more elevated and trigonal. The ridges, which are strong and numerous at the apex or in the young state, become faint towards the centre until they disappear near the ventral margin.

Pyrula nodulifera, G. B. Sowerby. Pl. V. fig. 2.

*P.* testâ oblongâ, spiraliter striatâ, ad angulum anfractuum nodulis obtusis coronatâ, supra medium nodulis inconspicuis cinctâ; spirâ brevi.

A shell so simple in form as a *Pyrula* can be safely described even from the fragmentary specimen figured, although the only characters are that it is spirally striated and has one row of obtuse nodules on the angle of the last whorl, and another row of very indistinct ones above the centre of the same whorl.

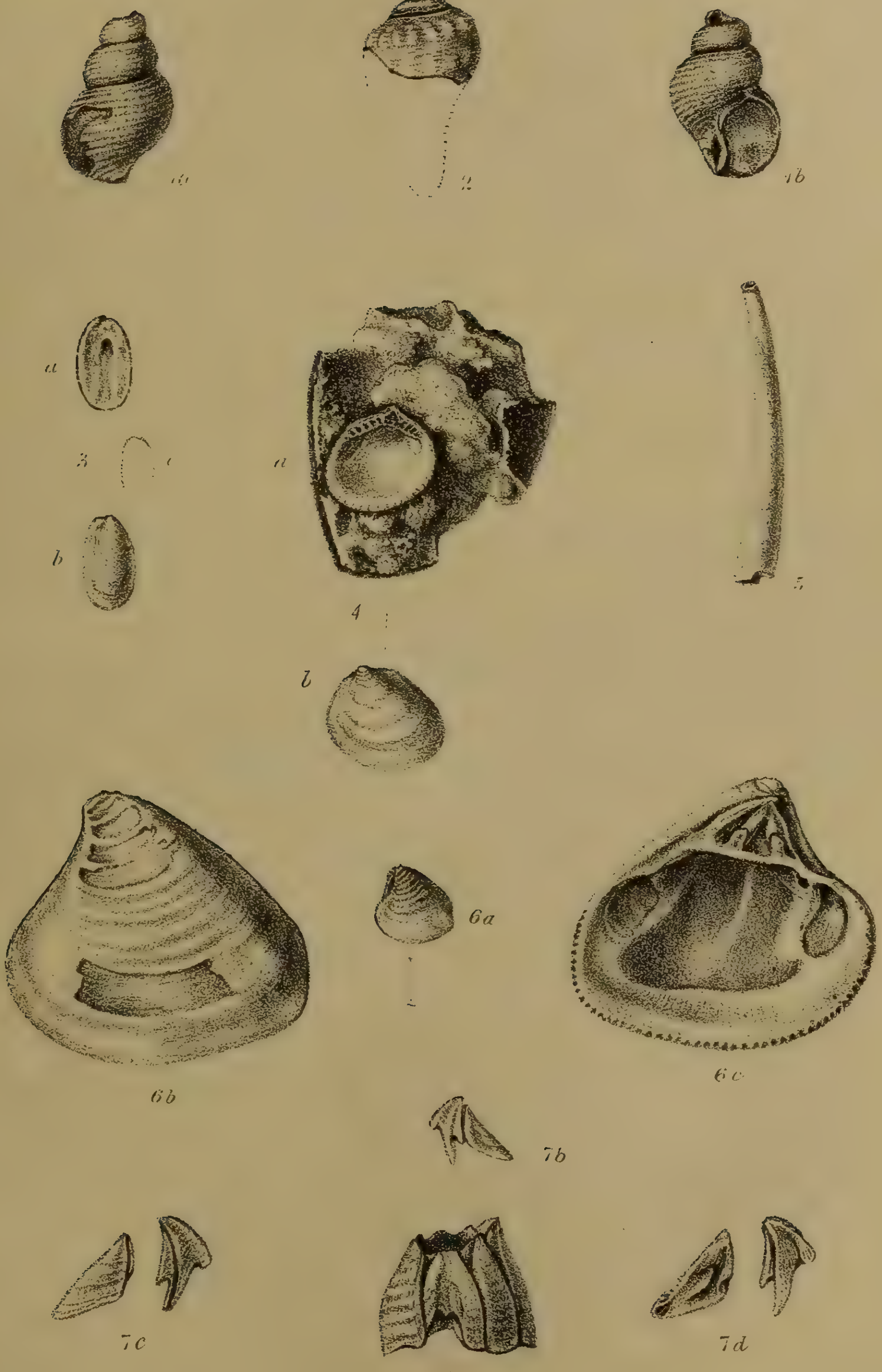
Buccinum concinnum, G. B. Sowerby. Pl. V. fig. 1.

*B.* testâ acuminatâ, spiraliter liris rotundis cinctâ; anfractibus rotundis; aperturâ subquadratâ; columellâ umbilicatâ; labio externo anticè paululum producto.

A neatly-formed, acuminated shell with rounded, spiral ridges upon rounded whorls. The aperture is rather square, with a narrow umbilical opening behind the columella, and (judging from the lines of growth) a slight forward curve in the outer lip.

### EXPLANATION OF PLATE V.

Fig. 1. Buccinum concinnum, *G. B. S.* *a*, *b*, two aspects.
Fig. 2. Pyrula nodulifera, *G. B. S.*
Fig. 3. Limax, sp. *a*, *b*, two aspects; *c*, nat. size.
Fig. 4. Limopsis aurita, *Wood.* *a*, in its matrix of clay; *b*, back view of a detached specimen.
Fig. 5. Dentalium.
Fig. 6. Astarte elevata, *G B. S.* *a*, nat. size; *b*, *c*, two views, magnified.
Fig. 7. Balanus Chisletianus, *G. B. S.* *a*, body of the shell; *b*, scutal valves of the operculum, nat. size; *c*, *d*, the same enlarged, and seen in two aspects.




G.B. Sowerby Lith.

W West imp.

FOSSILS FROM CHISLET, KENT.

7. *On the* Fossil Crustacean *found in the* Magnesian Limestone *of* Durham *by* Mr. J. Kirkby, *and on a* New Species *of* Amphipod. By C. Spence Bate, Esq., F.L.S., &c. (Communicated by Dr. H. Falconer, F.R.S., F.G.S.)

[Read June 23, 1858.]

[Plate VI.]

In January, 1857, a paper by Mr. Kirkby was read before the Geological Society*, on "some Permian Fossils from Durham," in which a few fragments were described as the remains of an extinct Crustacean. Some drawings of these were kindly submitted to me previously to their publication. One series I regarded† as being probably from the anterior portion of an Isopod; and the remainder I considered as not belonging to the same animal, but as parts of an Amphipod.

I have recently (since the reading of this paper) been allowed, through the kindness of Mr. Kirkby (to whom I applied in accordance with a suggestion from the Council of the Geological Society), the advantage of examining the original specimens of *Prosoponiscus problematicus*, together with others that have been discovered since the publication of his paper.

Having thus a favourable opportunity of reconsidering an opinion which was given from an examination of drawings only, I have been enabled to make out some points not portrayed in the drawings, which enable me to arrive at a more satisfactory conclusion. The specimens are the anterior and middle parts of an Amphipod; and none belong to an Isopod, as I at first informed Mr. Kirkby‡.

To show with any amount of certainty the correctness of this hypothesis, it is necessary that I should demonstrate, in recent Crustacea, an approximation of structure to that of the fossil. Assuming that, if certain known parts of an unknown animal agree in character with those homologically the same in an animal that we do know, we have *à priori* a right to infer the undiscovered portion of the one bears a corresponding relation to the remainder of the other.

Commencing with the anterior fragments, there are specimens of the cephalon with from two to four segments attached. The cephalon is large, deep, laterally compressed, and slightly carinated upon the dorsal surface, which carina is produced anteriorly into a small point. The eyes are round and prominently elevated. The posterior margin is slightly elevated. The inferior margin is stout and strong; and to this is attached part of an appendage, probably that of a mandible (fig. 5, *d*). This little fact was overlooked in the original drawings, probably from the close resemblance between the colour of the fossil and that of the rock of which it is a part. But this is more distinctly visible in the specimen from which fig. 6 is taken (*d*). It therefore must follow that the eyes are not (as

* Quart. Journ. Geol. Soc. vol. xiii. p. 213.

† In the communication read June 23, 1858; this paper having been somewhat modified since then by permission of the Council.

‡ Quart. Journ. Geol. Soc. vol. xiii. p. 214.

appeared in Mr. Kirkby's drawings*) situated at the extreme limits of the anterior inferior margin of the cephalon.

In *Isopoda* (except in Dana's tribe of *Anisopoda*) the eyes are external to both pairs of antennæ, whereas in the *Amphipoda* they are situated between the upper and lower antennæ.

The mandibles in the *Isopoda* articulate within the lateral margins of the cephalon; but in *Amphipoda* they articulate upon the lateral margins, posterior to the second pair of antennæ.

Posterior to the cephalon in the specimen (fig. 6) are at most four narrow segments, which are not as deep as the cephalon; they are laterally compressed and marked by a slight dorsal keel.

The other specimens consist of four or five narrow segments, and two large ones (one very large and the second nearly as large), situated posteriorly. The narrow segments are not more than half as deep as the larger segments, to each of which, in one or two of the more recently-found specimens, there is attached a small plate: these plates are the coxæ of the legs (the "epimera" of Edwards). These coxæ bear a resemblance to those of the recent Amphipod (*Phœdra antiqua*) in the annexed plate (Pl. VI. fig. 8). In the fossil the second segment of the pleon has the posterior margin ornate in the more perfect specimens, being toothed at the infero-posterior angle, and lobed near the middle, thus possessing a waved and graceful appearance (figs. 3 and 4).

Another specimen exhibits the commencement of a segment posterior to those already given; and slight indications of this may be seen in fig. 3.

The fragments that have been found belonging to this portion of the animal are laterally compressed, and, in all the specimens except one, are surmounted by a slight dorsal ridge.

That all the specimens are parts of the same Crustacean species, I think may be shown from the corresponding size and the relative depth of the segments of the pereion. The circumstance that one specimen is not carinated will scarcely interfere with this opinion, since it is evidently an exception to the rule, depending upon some peculiarity in the growth of the individual.

In the development of those *Amphipoda* that have a dorsal carina, the larva appears first without that distinguishing feature, which is afterwards gradually added. We can easily understand how a slight arrest in the growth of the animal may interfere with this peculiarity. Therefore, when an animal in its normal condition possesses a carina so very indistinctly marked as in the fossil, it is not unwise to assume that the absence of that character is but a slight divergence from the typical condition, therefore one of variety or sex.

We therefore come to the conclusion that the specimens belong to one species of animal, and that the animal is an Amphipod Crustacean, from the recent type of which it differs in the prominent eye and the greater depth of the anterior, as compared with the second, segment of the pleon.

* Ibid., pl. vii. figs. 1–3.

The prominent eye so characteristic in the fossil is a feature frequent among *Isopoda*. It was this, as much perhaps as anything else, that induced me at first to think that the fossil belonged to that order of *Crustacea*. Although more common among *Isopoda*, the prominent eye is not inconsistent with the structure of an Amphipod. It so exists in the genus *Phlias* of Guérin, and to a less extent in *Acanthonotus* of Owen.

Amphipods are generally laterally compressed; they have the segments narrower and shorter than those of the pleon. The squamiform coxæ are absent in many of the fossil specimens, particularly the anterior portion,—a circumstance that may be accounted for by the known habits of the animal, since it splits off the legs when it frees itself from the integument in moulting.

If the fossil be examined closely, each segment of the pereion will be found to be elevated posteriorly and depressed anteriorly; and it will be seen that a deep notch exists immediately behind the posterior margin of the first segment of the pleon. This imbricated appearance is evidently the result of the upper dorsal portion of the segments being on the stretch, while the lower or lateral margins of the same overlap each other. This shows that the remains were rolled upon themselves,—a condition which *Crustacea* very generally assume.

A feature, as before remarked, that is prominently peculiar in this fossil specimen is the remarkable difference between the size of the segments of the pleon and those of the pereion, the former being very long, the latter very short.

In *Amphipoda* generally, the segments of the pereion, as a rule, are shorter than those of the pleon, but not to any very great extent in the normal *Gammaridæ*. In the sub-family of the *Phoxides* we find it more conspicuous, but not so decidedly as in the fossil species.

Some two years since, I received from a kind and valued correspondent (the Rev. George Gordon), among many other specimens from the Moray Firth, an injured individual of an undescribed species of Amphipod, which I delayed to publish, from a desire of procuring specimens more perfect; but in this as yet I have been unsuccessful.

Those parts in the recent specimens, which I presume represent the fossil remains under notice, bear a generic resemblance to them.

The segments of the pereion, like those in the fossil, are short, while the segments of the anterior portion of the pleon are long. I am thus led to believe that the following description of the recent animal will be found to bear a close generic resemblance to the fossil species.

The head or cephalon is pointed above, and projects over the antennæ, the superior of which is short, somewhat pyriform, the basal articulation of the peduncle being much stouter than, and nearly as long as, the other two. Filamentary appendage short (?) and furnished with a complementary appendage, consisting of but a single joint. The inferior antenna, which is placed posteriorly to the upper, has the peduncle as long as the upper antenna. The coxæ of the legs are small and unimportant. Unfortunately the gnathopoda and anterior pereiopoda are missing; the three posterior are equal. The three anterior segments of the pleon are large; each being equal to the three or four of the pereion. The posterior pair of pleopoda terminate in two lanceolate rami. The telson is simple, squamiform, and lanceolate. In this particular species the third segment of the pleon is ornate—that is, fringed or ornamented along the posterior margin by a series of teeth,—and the posterior pleopoda have the rami equal.

It appears therefore that, with the exception of the carina on the dorsal line of the fossil specimen, and the ornate margin of the third segment of the pleon, the description might serve for both specimens, as far as known; and it is upon this close correspondence of the two, that I have constructed the figures in the accompanying plate (Plate VI. figs. 1 and 2) of *Amphipoda*, from the fossil specimens found by Mr. Kirkby, without the slightest straining of anatomical details. It is upon this approximation of the recent to the fossil, that I am induced to believe that the specimens are parts of an Amphipod, which, if correct, is, I believe, the first Crustacean of that Order yet recorded.

### EXPLANATION OF PLATE VI.

Fig, 1. *Prosoponiscus problematicus*, restored.
Fig. 2. ———————— rolled up.
Fig. 3. Four posterior segments of the pereion, and two anterior segments of the pleon, fossil. 3′ ligature between the segments, seen on the stretch. 3″ Posterior margin of the second segment of thc pleon in the fossil. 3‴ Posterior margin of the third segment of the pleon in the recent amphipod (*Ampelisca Belliana*).
Fig. 4. Two posterior segments of the pereion, and two anterior of the pleon.
Fig. 5. Cephalon and two anterior segments of the pereion; *d* part of mandible?
Fig. 6. Cephalon and four anterior segments of the pereion; *d* part of mandible?
Fig. 7. Cephalon; viewed anteriorly, partly imbedded in the matrix.
Fig. 8. *Phædra antiqua* (the unshaded parts are restorations); *z*. Telson,

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8. *On some* New Species *of* Eurypterus; *with Notes on the Distribution of the Species.* By J. W. Salter, Esq., F.G.S., of the Geological Survey of Great Britain.

[Deferred.]

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9. *Description of a New Fossil* Crustacean *from the* Lower Greensand *of* Atherfield. By Charles Gould, Esq. (Communicated by Professor Huxley, F.G.S.)

[Deferred.]

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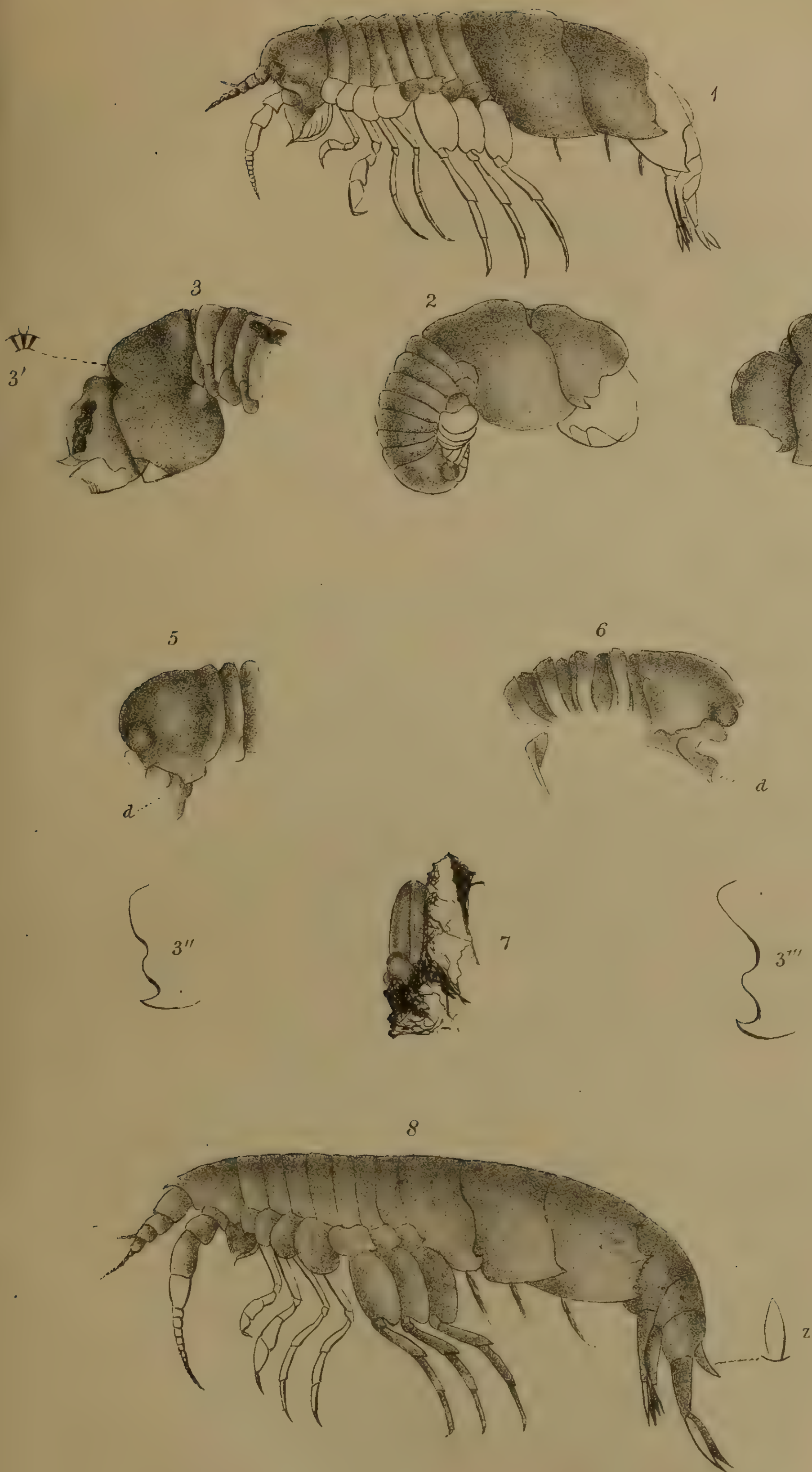


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RECENT & FOSSIL AMPHIPODA.

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## I. TRANSACTIONS AND JOURNALS.

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# PROCEEDINGS

OF

# THE GEOLOGICAL SOCIETY.

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## POSTPONED PAPERS.

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### *On some* Outline-drawings *and* Photographs *of the* Skull *of the* Zygomaturus trilobus, *Macleay* (Nototherium, *Owen?*). By Professor Owen, F.R.S., F.G.S., &c.

[Read March 10th*, 1858.]

[Plates† VII. and VIII.]

Sir R. I. Murchison placed in my hands a few days ago seven photographs, three of which are stereoscopic, of, perhaps, the most extraordinary mammalian fossil yet discovered in Australia.

These photographs, with a brief printed notice of their subject by Wm. Sharpe Macleay, Esq., F.R.S., and some MS. notes by J. D. Macdonald, M.D., R.N., had been transmitted to Sir Roderick by his Excellency the Governor Sir W. Denison, from Sydney, New South Wales; and it is by the desire of Sir Roderick Murchison that I now bring the subject under the notice of the Geological Society of London, to whom Sir Roderick desires to present the Photographs, on the part of His Excellency, Sir Wm. Denison.

I had, some weeks previously, received from my friend and correspondent, George Bennett, Esq., F.L.S., of Sydney, New South Wales, the accompanying outlines of the same fossil skull, made by him on the reception of the specimen by the authorities of the Australian Museum at Sydney, and I had penned notes of my comparisons of these sketches before receiving the photographs and descriptions of the fossil skull from Sir Roderick I. Murchison.

Mr. Macleay's description appears in a Report on "Donations to the Australian Museum during August, 1857," published in a Sydney newspaper of about the same date. It is as follows:—

"Fossil Skull of a new marsupial animal, which bears a nearer approach to

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* For the other Communications read at this Evening-meeting, see Quart. Journ. Geol. Soc. vol. xiv. p. 533 *et seq.*

† In Plate VII. the skull under description is figured, on a reduced scale, from casts received at the British Museum since the reading of this paper. See further on p. 176.

*Diprotodon* than to any other known genus. The size was apparently that of a large ox; and the skull agrees with that of the *Megatherium*, and others of the American tardigrade *Edentata* (living and extinct), in having a long apophysis descending from the zygomatic arch, as well as in other particulars. However, this process of the zygoma exists in the *Diprotodon*, and may be detected even in the Kangaroo. Another characteristic of this new quadruped, which may be called *Zygomaturus*, is the great distance of the zygomatic arch from the temporal bone. The breadth of the skull at the widest part—namely, about the centre of the zygoma—is fifteen inches; the extreme length of the skull is about eighteen inches. In the *Diprotodon* the skull is, on the other hand, about three feet long by one foot eight inches broad; so that, while the *Diprotodon* must have had a facies somewhat like that of a Kangaroo, the facies of the *Zygomaturus* must have been about as broad and short in proportion as that of a Wombat. The lower jaw of the specimen in the Museum is wanting; but the formula of dentition in the upper jaw is as follows:—6 incisors, 0 canines, 10 molars. The two front incisors are very long and strong, as in the Kangaroo and *Diprotodon*. The above dental formula agrees with that of *Diprotodon*, except that the latter animal had only eight molars in the upper jaw. The *Zygomaturus* had many points of structure approaching those of the Rhinoceros and Tapir family. For instance, the molars resembled in form those of the Tapirs, while the nasal septum may remind us of the *Rhinoceros tichorhinus*, a fossil species that formerly inhabited England and other parts of Europe. The strong and very prominent trefoil-shaped arch formed by the extremity of the nasal bones, shows that, if the *Zygomaturus* did not possess a snout like that of a Tapir, it must, at least, like a Rhinoceros, have had a horn (perhaps a double one) on the nose. Without doubt this horn was used for grubbing up the roots of aquatic plants, since, like the pachyderms, to which it bears so close an affinity, in all probability the *Zygomaturus* passed its life in marshy places. The extraordinary width of the temporal fossæ denotes that the animal possessed enormous powers of biting and mastication.

"This skull belonged to an adult animal, as the molars are considerably ground down.

"Also, the upper jaw of a young *Zygomaturus*, as appears by the tips of the molars being perfect.

"Another portion of an upper jaw, and a humerus, probably of a *Zygomaturus*; base of left ramus of the lower jaw of *Diprotodon*; and front incisors of ditto.

"All the above fossil remains are from King's Creek, Darling Downs, being the same locality whence the entire skull of the *Diprotodon* was obtained some years ago. Frederick Neville Isaacs, Esq., Gowrie, Darling Downs."

The notes of Dr. J. D. Macdonald, R.N. (Assist.-Surg. H.M. Herald), are without date, but appear to have been made from actual inspection of the fossil itself, probably on the occasion of the Doctor's visit to Sydney, in 1857; they are as follows:—

"*Zygomaturus trilobus* (Macleay).

"The photographic figures of the skull of this remarkable animal, executed by Mr. Wilson, require a few words of explanation, in order that some at least of the many queries which will naturally arise in the mind of an anatomist inspecting them, without the means of consulting the original, may be as it were anticipated and answered.

"First, then, the granular appearance of the surface is due to the adhesion of particles of grit and alluvial matter, which had not been removed in consequence of the extreme brittleness of the bone beneath.

"The tables of the skull are of great thickness, and thrown apart by large cellular cavities, lined with a compact osseous tissue. The frontal sinuses especially are of enormous size, divided by a thin vertical septum, and giving rise to the angular fulness of the antero-lateral part of the forehead. A small piece of the outer table having been broken away on the right side of the occiput, an opening remains, communicating with the cellular structure within, which bears the strongest analogy to that occurring in many pachyderms. Moreover, the several cranial bones exhibit a corresponding tendency to unite by anchylosis.

"The brain-cavity is exceedingly small, as might be expected from the above details; and its long axis very nearly corresponds with that of the cranium, which may be said to meet the general plane of the palate at an angle of 60°.

"The whole head may be divided longitudinally into three portions of nearly equal breadth; the brain-case, with its cellular parietes, &c., occupying the central, and the zygomatic arches the lateral, parts,—the forehead, nose, and palate, including the molar teeth, being equal in transverse measurement. The palatal arch is single and smoothly rounded off, so that the posterior nasal spine is absent. The lateral, thickened, and rounded nasal lobes are processes of the premaxillary bone, which unite with the maxillaries in a curved vertical suture with its concavity directed forwards.

"The tail-like process projecting downwards and backwards from the anterior and inferior part of the zygomatic arch has its homologue in the skull of many animals, even in that of man himself. It is, therefore, jointly composed of the malar process of the superior maxillary bone and the maxillary process of the malar bone, united by a vertical suture. This projection must have given attachment to the zygomatic muscles, and perhaps to a few of the anterior fibres of the masseter, although extending below the level of the upper molars. That of the left side has been slightly injured.

"The zygomatic process of the temporal rests upon that of the malar bone, with an oblique line of union running through the upper horizontal portion of the arch.

"The anterior convex border of the zygoma being nearly on a plane with the external angular process of the os frontis, and the remarkable manner in which the cranium is elevated on the facial bones, indicate very clearly that the eyes of this animal were directed forwards, admitting of convergent vision. The low position of the *optic foramen* also shows that the eyes must have been situated close to the orbital border (if it may be so called) of the superior maxilla."

*Notes on the Outline-drawings.*—One of the peculiar features of the skull of the phytophagous Marsupials, whether of the browsing Kangaroos and Potoroos, or of the leaf-and fruit-eating Koalas, Petaurists and Phalangers, or of the burrowing and root-gnawing Wombats, is the great strength, size, and span of the zygomatic arches, as compared with the answerable vegetable-eaters in the Placental series of Mammalia*.

This character is least marked in the true Kangaroos; but it is sufficiently distinctive of these as compared with the browsing or grazing Pecora of similar size: and there is a modification of the zygomatic arch in *Macropus* for extending the base of origin of the masseter masticatory muscle, which is present in no gyrencephalous† Herbivore, although it exist in the lissencephalous† Sloths and their great extinct herbivorous congeners the Megatherioids—I allude to the descending process from the fore part of the zygomatic arch (Plate VII. fig. 2, *z*).

In all those herbivorous mammals in which the grinding teeth present two transverse ridges, the zygomatic arches are well developed, the bony bar or plate being of great vertical extent: the Tapir, the Manatee (Plate VIII. fig. 1, *z*, fig. 3, *z*), and the Megathere

* See 'On the Osteology of the Marsupialia,' Zool. Trans. ii. p. 387, pls. 69 and 71.

† For the meaning of these terms see my 'Classification of the Mammalia,' in the 'Proceedings of the Linnæan Society,' Feb. 17 and April 21st, 1857.

show this relation, as well as the Kangaroo, Wombat, and Koala (fig. 2, *z*); and the temporal fossa is of considerable capacity, as it also is in the great Dinothere, which has the same type of molar teeth. The working of opposed double-ridged molars evidently requires a greater amount of muscular action than that of the more complex but flatter molars of the Ruminants, Horse, Rhinoceros, and Elephant.

The maximum development of the zygomatic arches, in connection with grinding teeth of the type of those of the Kangaroo and Tapir, is manifested by a most extraordinary Marsupial Herbivore, of the size of an ox, the cranium of which has recently been discovered in Pleistocene deposits at King's Creek, Darling Downs, Australia, and is now in the Museum at Sydney, N. S. Wales.

I am indebted to my friend Mr. George Bennett, F.L.S., for four carefully-made, and apparently most accurate, outline-drawings of this unique fossil, in which so much of the anatomical characters are given as have enabled me to make the requisite comparisons for a conclusion as to the nature and affinities of the, most probably, extinct Australian quadruped. The dentition of the upper jaw consists of three incisors and five molars on each side, of which the first appears to be a premolar and the rest true molars: *i. e., i.* $\frac{3-3}{}$, *c.* $\frac{0-0}{}$, *p.* $\frac{1-1}{}$, *m.* $\frac{4-4}{}$; agreeing, in this formula, with *Macropus* and *Diprotodon*.

The reduced size of the drawings does not permit one to infer more than a close general resemblance of the transversely-ridged molars of the fossil with those of *Diprotodon* and *Macropus*.

The modifications of this dentition resemble those of the *Diprotodon** in the retention of the premolar after the last true molar has come into place, and in the superior size of the first as compared with the second and third incisors. From so much of the sockets of the first incisiors as is indicated in a front view of the cranium, it may be inferred that they were scalpriform teeth, implanted by a long, simple, slightly-curved base, of equal diameter with the crown. Each lateral series of grinders is slightly curved with the convexity outward; the two series converge a little forward.

All the grinding teeth are worn; the anterior most, and the rest by degrees less, to the hindmost, which is least abraded: this indicates the course of their succession, and throws clear light on the ordinal affinities of the fossil.

In the Tapir, as in other placental terrestrial *Herbivora*, the number of true molars being $\frac{3-3}{3-3}$, and the first of these, *m* 1 (Plate VIII. fig. 4) coming into place and use before the last premolar *p* 4 (*ib*), the first molar presents a more worn grinding-surface than the tooth which precedes it, *p* 4: in the Kangaroo and other Marsupial *Herbivora*, the number of true molars is $\frac{4-4}{4-4}$; and, as they succeed each other from before backwards, the first of the four is always more worn down than the second, thus presenting conditions of the grinding-surface the reverse of those which would be presented by the

* See "Report on the Extinct Mammals of Australia," in 'Report of the British Association,' 1844.

Tapir, Stag, and placental *Herbivora*. If it were objected that the first and second of the five grinders in *Zygomaturus* or *Nototherium* may be deciduous teeth, destined to be succeeded by vertical successors or premolars, it may be replied, that no instance of the retention of deciduous molars with a last molar in place, and so worn as is the fifth grinder of *Zygomaturus*, has been observed.

A view of the upper molar series of a Tapir, soon after the last molar has come into place, is given in Plate VIII. fig. 4, to illustrate this difference from the state of the molar series in the Australian fossil (Plate VIII. fig. 5), in which the tooth, marked $d_4$, the fourth from the back end of the series, is much more worn than $m_1$, the third from the same end. This state of the dentition determines the marsupiality of this huge and most strange extinct quadruped as decisively as would the marsupial bones, had the entire pelvis been found.

All the cranial characters elucidating marsupial affinity concur with the dental ones in establishing it.

The brain was very small; its proper case makes no swelling from the inner wall of the temporal fossa (Plate VII. fig. 3, *t*) as it does in the Ox, Horse, Tapir, or other placental Herbivores of like size with the fossil. Equally indicative of the low condition of cerebral development is the inclination of the plane of the occiput from the condyles upward and forward, as shown in fig. 2, Plate VII.; and in fig. 3, taken looking directly upon the upper surface of the skull, in which the whole sloping occiput comes into view, divided from the upper surface by a super-occipital ridge which describes an open angle with the apex forwards. The constricted part of the cranium in advance of this ridge, and opposite the middle of the temporal fossæ*, marks the anterior boundary of the cranial cavity: the part *f* in advance, which gradually expands, answers to that part in the Kangaroo and Wombat which is occupied by the extensive cellular diploë, in communication with the nasal cavity†; such expansion of the pneumatic frontal bone is also found in the *Phascolomys latifrons*. The zygomatic arches, from their depth, thickness, outward span, and descending process (*ib.* fig. 2, *z*) present one of the most marked and peculiar features of the fossil skull from Darling Downs; the extent of the fossæ which they circumscribe, and their proportions to the rest of the skull, recall the features of that of the Elephantine Seal (*Cystophora proboscidia*); but the form and direction of the descending process, *z*, show this arch to be essentially an exaggeration of that of the Koala (Plate VIII. fig. 2) and Kangaroo. The descending process is, however, relatively larger and longer: in this respect it resembles the same part in the skull of the *Diprotodon*.

The power of the muscles of the mandible both for biting and chewing must have been enormous, and indicates some peculiar quality of resistance in the alimentary substances to be ground down. The grip of the strong and long anterior incisors, brought by the

* See 'Osteology of the Marsupialia,' loc. cit., pp. 380, 386.

† Ib. Part II. Trans. Zool. Soc., vol. iii. part iv. p. 303, plate 37. figs. 4 and 5.

shortness of the jaws within the power of the temporal muscles in a degree proportionately to the proximity of the inserted moving force, must have been like that of a vice.

The next peculiar feature of the present fossil is the small proportion of the facial to the cranial division of the skull. In Man and Apes the cranial division is coextensive with that part which forms the cavity for the brain; in lower quadrupeds it is bounded anteriorly by the orbit and fore part of the zygomatic arches, and usually includes the nasal and frontal sinuses, occupying a greater or less extent of the cranium anterior to the cerebral cavity. Defining the facial part of the skull of the present fossil, as the part in advance of the orbit (Plate VII. fig. 2), it forms, as it were, a short pedunculate appendage to the rest of the skull, increasing in both vertical and lateral extent as it approaches its anterior termination, or the muzzle. The lateral enlargement is due to an unusual rugous protuberant swelling of the sides of the nasal bones, or of the parts of the premaxillary articulating therewith: in the side view (fig. 2) may be discerned a suture, which indicates the swelling to belong to the premaxillary; but the upper view (fig. 3) does not show such suture. Only an inspection of the fossil itself can determine this point. The analogy of the Wombat and Kangaroo favours the conclusion that the premaxillaries united with the nasals.

In the Koala (*Phascolarctus fuscus*) and *Phascolomys latifrons* the fore part of the muzzle is expanded laterally by an outward swelling of the front border of the premaxillaries, just where they join the nasals (Pl. VII. fig. 5.); and both the Wombat and Koala resemble the fossil in question in the small proportion of the facial part of the the skull, as above defined. But in the fossil from Darling Downs, the lateral rough protuberances are continued along the anterior margins of the nasal bones, forming a thick and strong double arch, one over each nostril (Plate VII. fig. 4); the septum narium appears to have been continued forwards to near the above thickened terminations of the nasal bones. The upper surface of these bones seems not to have been roughened as in the Rhinoceros.

The length of the skull, as noted by Mr. George Bennett, on the sketches which have afforded subjects for the preceding remarks, is 1 foot 6 inches; its breadth 1 foot 3 inches.

By the dentition of the upper jaw, this fossil agrees in that essential character with the genus *Diprotodon*; but the dentition of the lower jaw might exhibit small incisors, superadded to the single large pair which is characteristic of *Diprotodon*, as of all known phytophagous marsupials. Supposing, as is most probable, that the lower jaw of the fossil in question had but two incisors, the next question would be, whether the peculiarity in the form and proportion of the skull, and especially in the position and aspect of the orbits, would justify a generic separation from *Diprotodon*, the dental formula being the same.

Another question also suggests itself,—whether, namely, the present skull may not belong to the same genus as that which I founded, under the name *Nototherium*, upon a mutilated lower jaw, with double cross-ridged molars, similar in number to those in *Diprotodon*, and presenting the same inferiority of size as the upper molars of the present fossil from Darling Downs show. Mr. George Bennett has inscribed the name "Zygomaturus" beneath the sketches he has transmitted, and informs me by letter, that such is the name which Mr. Macleay has provisionally given to the fossil in the Catalogue of the Sydney Museum.

The bony palate appears to have been entire, or without any unusually large palatal vacuity, in this respect resembling the same part in *Macropus major* and *Diprotodon*.

Whether this fossil prove to be a second species of *Diprotodon*, or a distinct genus; and in the latter case, whether distinct from *Nototherium*, or identical with it,—it forms the most extraordinary addition to the evidences of those extinct phytophagous quadrupeds of Australia which exhibited the marsupial type on a scale rivalling the Rhinoceroses and large Buffalos of the warmer parts of the Asiatic and African continents. Let us hope that good plaster casts of the unique specimen may be made and transmitted to Europe, to enable a further insight into its nature and affinities.

*Notes on the Photographs*.—Since the foregoing notes were penned I have had the opportunity, through the kindness of Sir R. I. Murchison, to inspect the photographs and photographic stereoscopes of the skull to which the name *Zygomaturus trilobus* has been given by Mr. Macleay.

The photograph, No. 4, shows most satisfactorily the close similarity of the two-ridged crowns of the upper teeth to those of the *Diprotodon australis*, figured in pl. 2 of my "Report on the Extinct Mammals of Australia"*, and removes whatever doubt might have been left after inspecting the pen-and-ink sketches by Mr. Geo. Bennett, as to the order of succession of the last four grinders, as indicated by the degrees of attrition of their crowns.

The same important evidence of the marsupiality of the species is yielded by the teeth in the two portions of upper jaw figured in the stereoscopic views beneath the principal fossils. There is a low transverse basal ridge before and behind the two chief ridges; these are slightly bent, with the concavity looking backwards: they have not the connecting processes extending from the fore part, as in *Macropus*, and herein lies the generic distinction from the Kangaroos; but the close conformity between *Macropodidæ*, *Zygomaturus*, and *Diprotodon* in all the minor modifications of the crowns of the grinding teeth, as well as in their number, relative size, and order of succession, bespeaks in an equal degree their family relationship.

The extent of each molar series in *Zygomaturus* is about 7 inches; in *Diprotodon* it exceeds 8 inches: the attachment of the front pier of the zygomatic arch in *Zygomaturus* is opposite to and almost coextensive with the three middle grinders (Plate IX.†

* 'Report of the British Association,' 1844.
† See the next Memoir.

fig. 5); in *Diprotodon* it is nearly opposite the interspace between the penultimate and last grinders, being of much less extent (*ib.* fig. 6).

A close inspection, with the lens, of the photograph of the upper surface of the expanded end of the muzzle, confirms me in the conclusion that it does not present that character which indicates the attachment of the horn in the Rhinoceros: the irregularity of surface is not so much upon the upper part as upon the sides of the nasal aperture, which sides are at their upper part peculiarly tumid: but these irregular bossy terminations of the bony muzzle are formed, as we are assured by Dr. Macdonald, by the premaxillaries, not by the nasal bones; and this is an additional ground for rejecting the idea that the present large extinct marsupial had a nasal horn like the rhinoceros.

The cavity of the nose "is divided by a complete bony septum to within one-fourth of the anterior aperture"* in the Kangaroo and common Wombat: since that remark was printed I have described the skull of a rarer species of Wombat, showing some features of resemblance to the *Zygomaturus*, not given by the previously-known kinds, and in which the bony nasal septum advances very close to the anterior outlet of the cavity. By this analogy, therefore, rather than by that of the extinct Tichorhine Rhinoceros cited by Mr. Macleay, I should be inclined to illustrate the significancy of the naso-septal feature in the cranial structure of the large Australian fossil.

I suspect that the swollen, tuberose, antero-lateral borders of the bony nostril (Pl. VII. fig. 4), so well shown in the photograph, have relation to some most unusual developments of the naked integument of the muzzle of the *Zygomaturus* or *Nototherium*, superadding an extraordinary feature to its low-set forward-looking eyes, and very broad low cranium. Future evidences of the forms and proportions of the limbs of this animal will be received with much interest.

Wholly concurring in Mr. Macleay's conclusions as to the marsupial nature of the fossil in question, I have to state that the British Museum has now received ample evidence that the generic distinction which Mr. M. believes to exist between that fossil and *Diprotodon* is not present. In the cranium of the *Diprotodon* in the Sydney Museum, of which photographs have been transmitted to me by Mr. George Bennett, the number of molar teeth in the upper jaw is reduced to eight, four on each side: but it is by the loss of the first small molar: and from the appearance of that molar in *Zygomaturus* I conjecture that it would, also, be shed in an older individual. But there are specimens in both the British Museum and the Hunterian Museum which demonstrate that the *Diprotodon* has five molar teeth developed on each side of both upper and lower jaws, as stated in my "Report on the Extinct Mammals of Australia"†.

* "Osteology of the Marsupialia," *loc. cit.* p. 391.
† *Op. cit.* 'Report of the British Association,' 1844.

## DESCRIPTION OF PLATES VII. AND VIII.

### Plate VII.

Fig. 1. Under view of the Cranium of *Nototherium Mitchelli*, Owen (*Zygomaturus trilobus*, Macleay): one-sixth natural size.
Fig. 2. Side view of the same: one-sixth natural size.
Fig. 3. Upper view of the same: one-sixth natural size.
Fig. 4. Terminal view of the nasal region of the cranium: one-sixth natural size.
Fig. 5. Similar view of the cranium of the Koala (*Phascolarctus*); one-half natural size.

[These figures, excepting fig. 5, are taken from the casts of the skull presented to the Trustees of the British Museum, and received since the reading of the foregoing paper. The original specimen is in the Museum of Sydney, N. S. Wales.]

### Plate VIII.

[The figures are reduced from specimens in the British Museum.]
Fig. 1. Cranium of *Manatus Americanus*.
Fig. 2. Skull of *Phascolarctus fuscus*.
Fig. 3. Cranium of *Tapirus Americanus*.
Fig. 4. Series of upper molar teeth of *Tapirus*, showing the greater attrition of the antepenultimate molar, *m* 1, in comparison with the tooth in advance, *p* 4.
Fig. 5. Series of upper molar teeth of *Nototherium*, showing the less attrition of the antepenultimate tooth in comparison with the tooth in advance.

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## *On a* Collection *of* Australian Fossils *in the* Museum *of the* Natural History Society *at* Worcester; *with* Descriptions *of the* Lower Jaw *and* Teeth *of the* Nototherium inerme *and* Nototherium Mitchelli, Owen; *demonstrating the identity of the latter species with the* Zygomaturus *of* Macleay.

By Professor Owen, F.R.S., F.G.S., &c.

(Read June 23rd, 1858.)

[Plate IX.]

Since the communication of the remarks on the photographs of the fossil cranium referred by Mr. W. S. Macleay to a new genus of *Marsupialia*, which he has called *Zygomaturus*, I have received, for examination, through the liberality of the Council of the Natural History Society of Worcester, a series of specimens of mammalian fossils from the Condamine River and Darling Downs, Australia; there have also arrived at the British Museum casts of the cranium, and of the upper jaw and teeth of the *Zygomaturus*, liberally presented by the Trustees of the Museum at Sydney, N. S. Wales, by which I am able to demonstrate that this cranium belongs, as I suspected it might, to the genus *Nototherium*, and to that species which, in my "Report on the Extinct Mammals of Australia," I dedicated to the then Surveyor-General of Australia, Col. Sir Thomas L. Mitchell*.

The Worcester collection of fossils, contributed chiefly by Mr.

* *Nototherium Mitchelli*: see p. 13 of Owen, 'On the Extinct Mammals of Australia,' 8vo. 1845, p.p. 21, Plate i—vi, 4to.; also, 'Catalogue of Fossil Mammalia, Mus. Coll. of Surgeons,' p. 314, Plates iii. and iv. 4to. 1845.

Hughes, from freshwater (pleistocene?) deposits of Darling Downs, contains the right ramus of the mandible of the *Nototherium inerme* (Pl. IX. fig. 3*), very closely corresponding with that figured in pl. 3 of my "Report" and "Catalogue." It fortunately includes sufficient of the symphysis to show the bottom of a socket of a small procumbent incisor. One of the differences between the cranium of the great *Diprotodon* and that of the smaller animal with double-ridged molars subsequently acquired is the relatively smaller size of the incisors in the so-called *Zygomaturus*. From the analogy of the *Diprotodon* and of its existing representatives, *Macropus* and *Phascolarctos*, the six upper incisors of *Zygomaturus* would be opposed by a single pair at the fore part of the lower jaw.

But this pair would be so much smaller in *Nototherium* than in *Diprotodon* as to leave no trace of their sockets in that part of the jaw—viz. beneath the two anterior molars—where the corresponding socket is widely excavated in *Diprotodon*: the difference in the size and position of the incisor-socket was, in fact, such as led me to infer that *Nototherium* did not possess a tooth developed to the degree which is indicated by the term "tusk"†; and the fossil jaw transmitted by Mr. Hughes proves such to be the case, and that the inferior incisor presented the same small proportional size, compared with *Diprotodon*, which the upper incisors of the so-called *Zygomaturus* present. Precisely the same characters which distinguish generically the lower molar teeth of *Nototherium* from those of *Diprotodon* distinguish the upper molars of *Zygomaturus* from those of *Diprotodon*. This concordance is carried out even to the minute markings of the enamel.

With respect to that character in the lower molars of *Nototherium Mitchelli*, I have remarked, "The dentine of the crown is encased in a sheath of enamel of nearly one line in thickness, with a smooth and polished surface, impressed at the outer part and near the base of the tooth, where the enamel is principally preserved, with fine parallel and nearly horizontal transverse lines‡." Precisely the same character is presented by the enamel of the upper molars of *Zygomaturus*. I then proceeded to state, "The smooth and polished exterior of the enamel covering the anterior part of the posterior eminence presents a striking contrast with the reticulo-punctate character of the enamel at the corresponding part of the molar in the *Diprotodon*§." The upper molars of *Zygomaturus* differ in the same way from those of *Diprotodon*.

Besides the well-executed casts of the cranium, and of part

* Drawn on the plate without reversal.

† "The anterior end of the symphysis (fig. 4) is broken away; but there is no trace there of the socket of any tooth; and it is too contracted to have supported any tusk or defensive incisor." (Extinct Mammals of Australia, 8vo, p. 12, 1845.). I erred, however, in supposing that incisors were absolutely wanting in the lower jaw of the smaller species, thence called *Nototherium inerme*: the analogy of the Rhinoceroses, however, supported the supposition that this species might differ from the larger *Nototherium Mitchelli* in the absence of those teeth.

‡ *Ibid.* p. 13. § *Ibid.*

of the upper jaw with upper molars, of the so-called *Zygomaturus*, the British Museum possesses a portion of the right side of the upper jaw with three molars of the *Nototherium* (Pl. IX. figs. 4 and 5), identical, at least in size, general configuration, and in the character of the enamelled surface, with the teeth in the lower jaw of that genus: the same collection also possesses an almost entire lower jaw of the *Nototherium Mitchelli* (Plate IX. fig. 1) from the formations cut through by the Condamine River, in the plains west of Moreton Bay.

I propose first to describe the ramus of the lower jaw of the *Nototherium inerme* (Plate IX. fig. 3), afterwards the almost entire mandible of the *Nototherium Mitchelli* (*ib.* figs. 1 and 2), and finally to point out the resemblances between the dentition of these jaws and that of the fragment of the upper jaw, and the casts of the fossil bilophodont skull, previously described.

The specimen of *Nototherium inerme* (fig. 3) transmitted by Mr. Hughes to the Museum of Natural History at Worcester, from the tertiary deposits forming the bed of the Condamine, consists of the right ramus*, and back part of the symphysis of the mandible, but with the condyloid, coronoid, and angular processes, and the fore part of the symphysis broken away.

The ramus is short, very thick in proportion to its length and especially its depth, convex on the outer side of the dentigerous part, slightly convex vertically on the inner side, and with the lower border describing a convex curve from the condyle to the symphysis, which seems to have been interrupted but slightly, if at all, by any projecting angle; for although the angle has been broken off, it has plainly been bent inward.

The fractured base of the condyloid process presents a triangular form, two inches in its longest diameter: the outer and most obtuse angle forms the hind part of the ridges bounding inferiorly the external coronoid fossa; the upper and most produced angle forms the back part of the base of the coronoid process; the inner and lower angle forms the same part of the angular process.

The outer part of the ascending ramus is divided into two facettes by the first-named thick ridge or rising of the bone, which extends from the outer side of the condyle obliquely downwards and forwards with a curve concave towards the external coronoid fossa.

The base of the coronoid process begins anteriorly one inch external to the socket of the last molar tooth, the hinder half of which tooth would be concealed by the process in a side-view†. The fractured base of the process extends to the condyle, with a slight curve concave outwards; it is about half an inch thick at the beginning, but soon diminishes to 3 lines and then to 2 lines in thickness, the plate of bone being thinned off, as it were, by the depressions for muscular insertion on both its outer and inner sides: it is $3\frac{1}{2}$ inches in extent to where it joins the fractured base of the condyloid pro-

* Drawn on the plate without being reversed.

† This is one of the specific characters of *Nototherium inerme*, given in the "Report," p. 12, and illustrated in pl. 3. figs. 1, 4.

cess. The base of the inflected angle is continued for 2 inches forward and inward from the same fractured base, and there is a well-marked depression on the inner side and above the base of this marsupially inflected angle: a little in advance of it the lower border of the ramus has been produced and slightly bent inwards, for the extent of 4 inches, as far forward as the penultimate molar: owing to its degree of production, which, however, was probably not great*, this inflected ridge or border has been broken away.

The posterior inlet of the dental canal commences at the back part of the thick convex rising which is continued forward on the inner side of the ascending ramus to the inner side of the last alveolus, and which rising divides the inner coronoid surface above from the surangular depression below: the foramen is situated 2 inches behind the last molar tooth, and on a rather higher level than the border of its alveolus: internal to it are a groove and a ridge: it is elliptical in shape, and 5 lines long in diameter: a smooth tract, concave lengthwise, of more than an inch, divides the ridge and the process from the inner and hinder part of the last alveolus, which process has been broken away, together with the border of the alveolus and the crown of the last molar.

The fore and aft extent of the last four molar teeth is 6 inches. Each of these teeth is implanted by two fangs. The fractured surface of the jaw in front of the first of these two-fanged teeth (Plate IX. fig. 3) shows the back part of the smooth vertical socket of a small anterior molar, of which no trace is perceptible in the somewhat more mutilated ramus, specimen No. 1505, on which (in the Museum of the College of Surgeons) the species *Nototherium inerme* was founded†. The fractured anterior surface of the mandibular ramus under description shows also the back part of the socket of a procumbent incisor, which alveolar surface, or bottom of a socket, is in advance of that of the first small molar.

The character of the *Nototherium inerme*, as originally given in my 'Catalogue of Fossil Mammalia' and 'Report,' &c., must be rectified by the addition of a fifth molar—the small anterior one; and of an incisor, shorter and relatively smaller than that of *Diprotodon*, in each ramus of the lower jaw.

The fore part of the dental canal is exposed immediately external to the back wall of the incisor socket, where it is reduced to the diameter of 3 lines.

The depth of the ramus of the jaw behind the symphysis is 3 inches; and it is the same behind the penultimate molar. The thickness of the ramus behind the symphysis is 1 inch 8 lines; but it increases by the convex outswelling of the outer surface to 2 inches 3 lines behind the penultimate molar.

The crown of the last molar (fig. 3, $m_3$) has been broken away; its base measures, in length 1 inch 10 lines, in breadth 1 inch

* According to the analogy of *Nototherium Mitchelli*, specimen No. 1506 Mus. Coll. Chir., where this ridge is entire.

† 'Catalogue of Fossil Mammalia,' Mus. Coll. Chir. 4to. 1845, p. 314.

3½ lines; this is the anterior lobe; the posterior one is narrower. Each fang is longitudinally excavated at the surfaces next each other; and the outer part of the root, so defined, is thicker than the inner part.

The crown of the penultimate molar is in length 1 inch 9 lines, in breadth 1 inch 3 lines, in height 8 lines: the dentine is exposed at the summit of each ridge.

The two ridges or bilophodont type of the molars of *Nototherium* were indicated rather than demonstrated in the specimens Nos. 1505, 1506, and 1507*, on which the genus was founded. The first complete lower molar which I have yet seen is the penultimate one of the jaw under description†. The crown is girt at the base by a cingulum, developed behind into a low talon, and interrupted at the outer and inner end of the main ridges, and for a greater extent at the inner than at the outer sides.

The horizontal contour of the crown is rather rhomboid than quadrate; for the hind lobe is more internal in position than the front one: and the ridges run, not in a line directly across the alveolar border, but from without inwardly and a little backwardly. The fore part of the outer end of each ridge is a little produced, most so in the hinder one, in which the produced part, inclining inwards, terminates, or abuts below, upon the middle of the base of the front ridge: the anterior part of the inner end of each ridge is a little produced forward, in an angular form; the general result is, that the summit of each ridge is slightly concave forward, convex backward.

The enamel is, for the most part, smooth and polished: the delicate striæ of growth are well marked, when viewed by a pocket lens, on the outer side of the tooth, and the same power brings into view a few punctations on the hinder slope of each ridge: the enamel is rather thicker on this slope than on the front one, and seems more so from being more obliquely abraded, from before downward and backward: so exposed, the coronal surface of the enamel is a line in thickness: the tract of dentine abraded in the present tooth is 2 lines across. The hinder talon, or part of the cingulum, is most developed: the front one seems as if destroyed by pressure of that of the preceding molar.

The antepenultimate tooth, or third counting backwards, measures 1 inch 6 lines in long diameter, and 1 inch 2 lines across the hinder lobe: the talon at the back of this lobe is as well developed relatively as in the penultimate molar: there is the same ridge or production from the outer and front angle of the back lobe obliquely towards the middle of the front lobe: much of this lobe has been broken away. The two fangs of the second molar show a fore and aft extent of at least 1 inch 2 lines for the crown of that tooth, with an extreme breadth of 8 lines. That a still smaller tooth preceded it is indicated, as before remarked, by a part of its socket.

* Mus. Coll. Chir.

† It shows the accuracy of the conjecturally dotted outline of the grinding surface of the entire molars, given in plates 3 and 4 of the 'Report.'

From the evidence of the ramus of the jaw in question, it thus appears that the genus *Nototherium*, as represented by the smaller species, *Not. inerme*, was characterized by at least five molars in each mandibular ramus, and by a procumbent incisor, of less relative size than in *Diprotodon*; its socket not extending back beneath the anterior molar.

From the *Diprotodon* the *Nototherium* differs, in both *Not. inerme* and *Not. Mitchelli*, in the polished surface of the enamel, as contrasted with the reticulo-punctate surface of enamel in the corresponding teeth of *Diprotodon*. *Nototherium* also differs in the oblique production, or ridge, from the outer and fore part of each lobe of the molar; by which it approaches nearer to *Macropus*, where such ridges are more developed.

The second species of *Nototherium* (*N. Mitchelli*) was founded on the posterior half of the left ramus of the lower jaw, now in the Museum of the Royal College of Surgeons (No. 1506, Catal. of Foss. Mam. 4to, p. 316, 1845), containing the last two molar teeth, which differed in their more advanced position, in reference to the coronoid process, from the *Not. inerme*. In a collection of Australian fossil remains, lately acquired by the British Museum*, there is an almost entire lower jaw (Plate IX. figs. 1 and 2), the hinder half of the left ramus of which precisely corresponds in size and shape with that of the *Nototherium Mitchelli*, and the fore part of which also shows the first small single-rooted molar; and in advance of its socket, the base of that of a procumbent incisor, having the same small relative size as compared with *Diprotodon*, which the lower jaw of the *Nototherium inerme* exhibits. The condyloid, coronoid, and angular processes, together with the fore part of the symphysis, are broken away in this specimen.

The back part of the ascending ramus below the condyle is bent or produced inwards, so as to form a deep concavity on the inner side of the base of that process. The inward production subsides, however, before it reaches the ordinary position of the angle of the jaw, from which it is separated by a smooth tract, where the outer surface is continued into the inner surface, without any production. Below this, the thick posterior and inferior border of the ascending ramus is again bent inwards, but in a rather less degree than the part above. The depression on the outer side of the coronoid process much resembles that in *Nototherium inerme*; but the fore part of that process commences at a greater distance external to the alveolar tract, as well as being opposite to the back instead of the middle part of the last molar tooth. A low ridge is continued from the middle of the back part of the socket of that tooth backwards to the process marked *b* in figs. 2 and 3, plate 4, of my original memoir on the genus *Nototherium*, and which is described there as "a broad platform of bone on the inner side of the base of the coronoid process." The entry of the dental canal is situated behind this platform, close to

* At an auction at Messrs. Stevens's, King Street, Covent Garden; and stated to have belonged to a Mr. Boyd.

the coronoid process, and distant from the last alveolus 2 inches 9 lines. The coronoid process has the same extensive fore and aft origin, and the slight transverse diameter as in *Nototherium inerme*, but is rather more concave externally.

The outer side of the horizontal ramus of the lower jaw of *Not. Mitchelli* is as convex as in *Not. inerme*; but it has a greater relative depth compared with the size of the molar teeth: this depth taken at the mid part of the last molar in *Not. Mitchelli* is 3 inches 9 lines: in *Not. inerme* it is only 2 inches 10 lines.

The long (fore and aft) diameter of the last molar in *Not. Mitchelli* is 1 inch 10 lines: the breadth of its front lobe is 1 inch 5 lines. The hind lobe is narrower. The cingulum is interrupted on the inner end, but not on the outer end of this lobe, behind which it swells into a talon of two lines breadth. The cingulum is interrupted at both the outer and inner ends of the front lobe, and is reduced in breadth where it is overlapped, at the outer half of the fore part of the tooth, by the talon of the next molar. The two ridges show the same degree of anterior concavity, and oblique production, of their outer and front angles as in *N. inerme*.

The penultimate molar is 1 inch 9 lines in long diameter, 1 inch 4 lines in breadth; it closely corresponds with that tooth in *Not. inerme*, but has been more abraded in the present specimen. The antepenultimate or third tooth (Plate IX. figs. 1 and 2) is 1 inch 6 lines in long diameter, 1 inch 2 lines across the hind lobe, which is rather the largest.

The socket of the second tooth (*ib.* $d_4$) indicates it to have had a long diameter of 1 inch $3\frac{1}{2}$ lines. The first tooth (*ib.* $p_3$) was, apparently, but 5 lines in long diameter, and was implanted by a single fang.

The extent of the five sockets is 7 inches 3 lines; that of the last three sockets is 5 inches 2 lines; the same extent is 5 inches in *Nototherium inerme*.

The back part of the symphysis in *Nototherium Mitchelli* is opposite the interspace between the third and fourth molar; in *Not. inerme* it is opposite the middle of the third molar. A longitudinal extent of 5 inches 3 lines of the symphysis, *i. e.* for $1\frac{1}{2}$ inch in advance of the first molar, is preserved on the left side of the lower jaw here described; and beneath this part the alveolus of the procumbent incisor penetrates to a depth of 1 inch 9 lines: and that socket indicates a somewhat relatively larger incisor than in *Nototherium inerme*; yet one much less, both absolutely and relatively, than in *Diprotodon*. What the entire length of the symphysial part of the jaw has been in advance of the molar series cannot be determined, owing to the unfortunate fracture of that part in the present specimen.

The total length of the left ramus (mutilated at both ends) is 1 foot 2 inches. The breadth of the mandible across the first molar alveolus is 2 inches 6 lines; but the jaw swells out as it descends. In front of this alveolus the jaw contracts suddenly at its upper border to a breadth of 1 inch 6 lines, and then begins to expand as it advances; this is a very significant evidence of the relationship of *Nototherium Mitchelli* with the cranium of *Zygomaturus*. The sides of the upper symphysial channel, in advance of the first molar, terminate above in a ridge, which is concave outwards, through the lateral contraction in front of the molar series. The anterior outlet of the dental canal is situated 1 inch 3 lines below this ridge, opposite the fore part of the socket of the first molar.

The right and left molar series converge a little anteriorly, with a slight concavity towards each other. From the outside of the socket of the right to that of the left last molar is 5 inches 6 lines; the extreme breadth of the lower jaw at the same part is 7 inches 9 lines, which is due to the great outswelling of the rami at that part. At the under and back part of the symphysis there is a semicircular depression, 1 inch 8 lines, across, bounded anteriorly by a sharp wall, concave backwards.

Such are the chief additional facts relative to the structure of the lower jaw and teeth of the *Nototherium Mitchelli*, which are derivable from the more perfect specimen in the British Museum, as compared with the original, in the College of Surgeons, on which the species was founded. There remains to be determined the degree of correspondence between this lower jaw with its dentition, and the cranium and teeth of the bilophodont marsupial to which the name *Zygomaturus* has been applied.

The photographic figures, and the subsequently received cast of that cranium, showed a well-marked difference from *Diprotodon* in the much greater extent of the anterior origin or base of attachment of the zygomatic arch in the smaller bilophodont marsupial: and this character has served to determine the nature of a portion of the right side of the upper jaw, with three molar teeth, and an almost cöextensive anterior base of the zygomatic arch (Plate IX. fig. 5) of a similar-sized bilophodont forming part of the collection of Australian fossils in the British Museum. The difference between this and *Diprotodon* is most conveniently exemplified by an almost similar fragment of the right upper jaw, with the anterior base of zygomatic arch (*z*) and a single molar ($m_2$), with part of the sockets of the preceding and succeeding tooth (*ib.* fig. 6), in the collection of fossils sent by the Natural History Society at Worcester. The difference above pointed out in the surface of the enamel of the lower molar teeth of *Nototherium* and *Diprotodon*, is here as strikingly exemplified in the enamel of the upper molars. The ridges, instead of being directly transverse as in *Diprotodon*, show the same slight degree of obliquity as in the lower molars of *Nototherium*. The summits of the ridges show a slight concavity directed backwards, due in part to the production of the inner and back part of each ridge,—a modification which, from the analogy of *Macropus*, might have been anticipated in the upper molars of *Nototherium*.

The fore and aft extent of the three molars in the present fragment of upper jaw corresponds with that of the three middle molars of the lower jaw of *Not. Mitchelli*; their transverse breadth is greater in the degree usually noticed in comparing upper and lower molars of the same herbivorous animal. The last of the three upper molars shows the surface produced by the pressure of the tooth beyond it; and its hinder ridge shows the same proportion of minor breadth as in the penultimate molar in the cast of the cranium of *Zygomaturus*.

The cingulum forms a ridge along the back part of this molar, of about a line in breadth: the anterior basal ridge is broader, and of greater transverse extent. The enamel on the worn ridges shows the same thickness as in the lower molars of *Nototherium*. The long diameter of the crown is 1 inch 10 lines, the cross diameter is 1 inch 8 lines. The posterior fang, which is exposed, continues of the same breadth for 2 inches within the socket, without dividing. A linear indentation divides the fang from the back part of the enamelled crown.

The middle (antepenultimate or third) molar ($m_1$) is 1 inch 6 lines in long diameter, and nearly the same in cross diameter; its anterior talon is also thicker than the posterior one.

The anterior molar ($d_4$), answering to the second in the lower jaw of *Nototherium*, has the two ridges obliterated and worn down to a common field of dentine, with the enamel-wall thickened and encroaching angularly at the middle of the inner side, where the mid valley ended in the younger state of the tooth. This greater degree of attrition of the permanent tooth in advance of the antepenultimate grinder, is a surer proof of the marsupiality of the great Herbivore than would be the marsupial bones themselves*.

The molar teeth in the cast of the skull of the *Zygomaturus* present, as already remarked, the same configuration as the teeth in the fragment of skull above described: the fore and aft extent of the three corresponding teeth in the cast, viz. the second, third, and fourth, is 4 inches 3 lines: their crowns are less abraded. The portion of bony palate preserved in the fragment of the skull shows the same entireness as in the cast of the entire skull. The three molars exhibit the same slight degree of convex outer, and concave inner, contour as do the corresponding molars in the entire series.

The three molar teeth in the fragment of upper jaw unequivocally belong to the same genus, and almost as clearly to the same species, as do the lower jaw and teeth of *Nototherium Mitchelli*. When the molar teeth in that lower jaw are applied to the molars in the cast of the upper jaw of *Zygomaturus*, it is difficult to imagine that they have not belonged to the same individual animal,—the correspondence is so close. The indication, slight as it is, of an expansion of the symphysial part of that mandible in advance of the constriction at its beginning in front of the first molar, is most satisfactory, as showing the same peculiar feature which distinguishes the short premaxillary part of the cranium.

I conclude, therefore, that the cranium, of which we now possess the cast (Plate VII. figs. 1-4), the fragment of the upper jaw with the molars (Plate IX. figs. 4 and 5), the almost entire under jaw

* The Monotremes have marsupial bones, although no marsupial pouch: the Thylacine has the marsupial pouch, but no marsupial bones.

(*ib.* figs. 1 and 2), and the right ramus of the under jaw (Plate IX. fig. 3) (in the Natural History Museum at Worcester), which form the chief subjects of the present communication, belong to one and the same genus, for which, according to the title of priority, the name of *Nototherium* must be retained.

The entire cranium, the portion of the upper jaw, and the almost entire lower jaw belong to the larger species, or form, of *Nototherium* which I have called *Not. Mitchelli.* The right ramus of the under jaw (Plate IX. fig. 3), and the upper jaw, with the molar series on each side, of which a cast has also reached the British Museum, belong to the smaller species, or form, called *Nototherium inerme.* It remains to be seen whether this may not be the female, and the larger form the male, of the same species of *Nototherium.* The difference of size between the two sexes of the Kangaroos renders the above conjecture extremely probable.

I subjoin the determinations of forty-eight specimens of Australian Fossils, transmitted, at the suggestion of the President of the Geological Society, for my examination, from the Museum of the Natural History Society of Worcester, by the liberality of the Council of that Society. These specimens were collected by Mr. Hughes, in Darling Downs, and exemplify the richness of the fossil evidences of Mammalia, and the association of particular genera in one limited locality.

*List of Mammalian Fossils from Australia in the Museum of the Natural History Society of Worcester.*

1. Upper jaw of *Macropus Titan*, mas.
2. Lower jaw of *Macropus Titan*, fœm., left ramus.
3. Lower jaw of *Macropus Titan*, right ramus.
4. Lower jaw, *Macropus Atlas*, fœm.
5. Right humerus, *Macropus Atlas.*
6. Lower jaw, *Macropus Ajax.*
7. First }
8. Second } phalanges of the middle toe of fore foot of *Macropus Titan* ?
9. Third }
10. Right acetabulum and part of pelvis of *Macropus Titan* ?
11. Right acetabulum and part of pelvis of *Macropus Atlas* ?
12. Right acetabulum of *Macropus Anak.*
13. Lower jaw, *Macropus Anak.*
14. Left humerus, *Macropus.*
15. Shaft of part of right tibia, *Macropus Titan* ?
16. Upper part of shaft of right femur, *Macropus Titan* ?
17. Metatarsus of largest toe, hind foot, *Macropus Titan* ?
18. Proximal phalanx of ditto, *Macropus Titan* ?
19. Proximal end of right tibia, *Macropus Atlas.*
20. Part of shaft of right tibia, *Macropus Atlas.*
21. Distal end of right tibia of *Macropus Titan.*
22. Distal end of right tibia of *Macropus Titan*, mas.
23. Distal end of left tibia of *Macropus Atlas* ?
24. Caudal vertebra, *Macropus Titan* ?
25. Caudal vertebra, *Macropus Titan* ?
26. Part of left ramus of lower jaw of *Diprotodon australis.*
27. Part of upper jaw of *Diprotodon australis.*
28. Part of right ramus, lower jaw, *Nototherium inerme.*
29. Part of right ramus, lower jaw, *Diprotodon.*
30. Part of right ramns, lower jaw, *Diprotodon.*
31. Portion of acetabulum, *Diprotodon* ?
32. Part of a molar tooth, *Diprotodon.*

33, 34. Fragments of ribs (*Macropus Titan*?).
35. Metacarpal, *large Macropus.*
36, 37, 38, 40, 42. Fragments of ribs, *Nototherium* or *Diprotodon.*
39. Shaft of radius, *large Macropus.*
41. Shaft of femur, *large Macropus.*
43. Proximal end of right ulna, *Nototherium* or *Diprotodon.*
44. Fragment of ischium.
45. Caudal vertebra of *Diprotodon.*
46. Right calcaneum, *Macropus Titan*?
47. Proximal half of large metatarsal of *Macropus Titan.*
48. Large metatarsal of *Macropus.*

## DESCRIPTION OF PLATE IX.

[The originals of figs. 1, 2, 4, and 5 are in the British Museum; those of figs. 3 and 6 are in the Museum of Natural History, Worcester.]

Fig. 1. Upper view of a mutilated lower jaw of *Nototherium Mitchelli*; one-fourth natural size.

Fig. 2. Side-view of the same jaw. *i*, socket of incisor; *p* 3, first molar, answering to the third premolar of the Diphyodont type; *d* 4, second molar (socket of), answering to the last deciduous molar; *m* 1, *m* 2, and *m* 3, *Nototherium*, answering to the first, second, and third true molars of the same type: one-fourth natural size.

Fig. 3. Upper view of mutilated right ramus of the jaw of *Nototherium inerme*; one-fourth natural size.

Fig. 4. Side view of three teeth, upper jaw, of *Nototherium Mitchelli*; half natural size.

Fig. 5. Under view of the same portion of upper jaw, showing the broad base of the front root of the zygoma; one-third natural size.

Fig. 6. Portion of the upper jaw, with a grinding tooth, showing the narrow base of the front-root of the zygoma, *Diprotodon australis*; one-third natural size.

THE

# QUARTERLY JOURNAL

OF

# THE GEOLOGICAL SOCIETY OF LONDON.

## PROCEEDINGS

OF

## THE GEOLOGICAL SOCIETY.

November 3, 1858.

The Rev. A. S. Farrar, M.A., Fellow of Queen's College, Oxford, was elected a Fellow.

The following communications were read:—

### 1. *On some* Natural Pits *on the* Heaths *of* Dorsetshire. By the Rev. O. Fisher, M.A., F.G.S.

[Abstract.]

On Affpuddle Heath and Piddletown Heath, near Dorchester, at an elevation of rather less than 500 feet above the sea, the surface is pitted with circular or oval hollows, like inverted cones, having occasionally a double apex. Their number is very great; and only the largest are marked in the Map of the Ordnance Survey.

They usually vary from about 60 to 80 yards in circumference; but one measures 130 yards, and another, called "Culpepper's Dish," is 290 yards round: in the former the sloping sides are 23 yards high; in the latter 47 yards. After observing that these pits could not have been formed by the washing away of the underlying sand-beds, the author proceeded to show that their formation seemed to be due to the subsidence of the material into "sand-pipes" in the subjacent chalk, owing to the percolation of rain-water containing carbonic acid, which dissolved the chalk; and Mr. Fisher referred to the explanation of this process given by Mr. Prestwich in a paper formerly read before the Society*.

It is evident, that wherever a sand-pipe has been formed there a pit *must* have appeared on the surface, though the bottom of the pit may have been many feet above the chalk-surface; as we see a conical depression formed in the surface of the sand in the upper bulb of an hour-glass as soon as it begins to run. The Heaths in question would, therefore, illustrate the normal condition of every surface covering sand-pipes; and, if no pits occur, the surface must have subsequently been levelled by some agency or another. As this process could have gone on only during a subaërial condition of the surface, and must have occupied a very long time, the author remarks, that the larger pits on the Heath referred to must have been formed by the sinking of the Eocene beds into enormous "sand-pipes" during an extended geological period, and that the area they occupy was dry land during all that time, and has been so ever since, or the pits would have been obliterated; and must therefore have formed islands or headlands in the sea, which last filled the adjacent valleys and gave them their present configuration. The denuded chalk-valley separating the two Heaths is in most parts destitute of gravel, and contains numerous pipes full of Eocene materials, proving that there was a period during which large pipes were formed anteriorly to the denudation; while the nearness of the pipes to each other shows that the great number of the pits is no argument against the cause assigned to them.

As the formation of these pits was subsequent to the outspread of the superficial gravel of these Heaths, and previous to the last depression and elevation of the land, their date would be perhaps near that of the great mammalian fauna. The author also explained his views of the method by which the subsidence of the materials gave rise to the peculiar shape of the pits (for, however deep the original depression, and of whatever shape, the sides would always eventually assume the angle at which the materials would stand); and he observed that somewhat similar depressions have been noticed in the neighbourhood in process of formation at the present day.

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2. *Notice of the Occurrence of an* Earthquake *along the* Northern Edge *of the* Granite *of the* Dartmoor District *on the 28th of* September, 1858. By G. Wareing Ormerod, Esq., M.A., F.G.S.

On the evening of Tuesday, the 28th Sept. last, a slight shock of an earthquake was felt in the district adjoining the northerly edge of Dartmoor; and it appears to have been almost entirely confined to

* Quart. Journ. Geol. Soc. vol. x. p. 241.

the vicinity of the junction of the granite and the Carbonaceous rocks. Crediton is the most north-easterly point at which, as far as I can gain information, the occurrence was noticed. No vibration of the ground was there felt, but a rumbling noise was heard, attributed at the time to a supposed explosion of the Gunpowder Mills on Dartmoor. No such explosion, however, had taken place. Crediton is on the spur of New Red Sandstone that extends thence in a westerly direction, by Bow and North Tawton, to Exbourne; this last place is situated about four miles to the north of Okehampton. No vibration or sound was noticed at either of the three last-named places, or to the south of Crediton, at Exminster, Kenton, Star Cross, or Teignmouth, all on the same geological formation. The Carbonaceous rocks lie to the west, between the New Red Sandstone and the granite of Dartmoor, which they adjoin on the east, north, and west sides. At Chudleigh and Hennock, both on the Carbonaceous rocks, no sound nor vibration was perceived on the 28th; but at Trusham, to the north of Chudleigh, on the same formation, on the evening of Thursday the 30th, a noise was heard, which a person who had resided in a country subject to earthquakes immediately recognized as arising from that cause. At Bovey Tracey, partly on the same formation and close to the edge of the granite, no sound nor vibration was perceived.

At Druids, on the Devonian beds, and near the edge of the granite, about a mile to the north-west of Ashburton, a rumbling noise, like that caused by a carriage passing over gravel, was heard on the 28th about 7 P.M. The flexure marked in the Map of the Geological Survey as passing between Ashburton and Druids does not run to the south of the last-mentioned place, which is shown, by the numerous fossils there existing, to be on the Devonian beds. This is one of the flexures mentioned by Sir Henry De la Beche in the 'Memoirs of the Geological Survey*,' as giving to the Carbonaceous rocks or Culm-measures of Central Devon the appearance of dipping beneath the argillaceous slates, limestones, and trappean rocks of Ashburton and Buckfastleigh. At Ashburton neither sound nor motion was noticed.

The earthquake was not, I believe, noticed at any place on the Carbonaceous rocks along the eastern edge of the granite south of Drewsteignton. At Lustleigh, Manaton, the Vitifer Mines, and North Bovey, all on the granite, neither sound nor motion of the earth was perceived. At Moreton Hampstead (on the granite), about a mile and a half to the north-east of North Bovey, no motion was felt, but a sound resembling the roar of a furnace was heard. At a farm, on the granite, about half-way between Moreton Hampstead and Chagford, the farmer heard a sound, and mistook it for the noise of a cart that was expected; he rose from supper, lighted his lantern, and went out to meet it.

At Chagford, on the granite, both sound and motion were noticed.

* Vol. i. p. 85.

Here, shortly after eight o'clock, my attention was withdrawn from the writing upon which I was engaged by a low rumbling sound, which lasted for a few seconds; and, like many others, I thought that an explosion had taken place at the Powder Mills. I did not feel any motion; but at the next house but one the vibration was so great as to make the china rattle and cause alarm. At other houses chairs were moved and the candles were observed to oscillate; and china, windows, and doors were shaken. A person who was at the time attending service at the Wesleyan Chapel informed me that he heard a noise that was not like thunder, and he did not know what it was like,—that it was first at his back, then seemed going by the side of the chapel, and then it came in at the windows at the end: this gives the direction of the shock as from E.S.E. to W.N.W.

At Teigncombe, a hamlet about two miles to the west of Chagford, and close to the open moor, a sound and vibration were noticed, and cups and plates on a dresser rattled. Between Chagford and Drewsteignton, at Sandy Park and Dogamarsh Bridge, on the granite close to the edge of the Carbonaceous rocks, the same sound was heard. A person described it as coming from Drewsteignton, and then passing on towards Kestor Kock,—that is, nearly from N.N.E. to S.S.W., and then turning to the west. At Cheriton Bishop, on the Carbonaceous rocks, between Drewsteignton and Crediton, about three miles from the former and five from the latter, no sound nor motion was heard on the 28th; a motion of the earth and sound were, however, noticed there and at Fingle Bridge over the Teign, contemporaneously, about the commencement of September.

At Drewsteignton, on the Carbonaceous rocks and near to the edge of the granite, a loud rumbling noise was heard on the 28th Sept., and some houses were so much shaken that the inhabitants ran out in alarm. At the nearly adjoining villages of Ramsleigh, South Zeal, and Sticklepath, about five miles to the west of Drewsteignton, on the Carbonaceous rocks, there much intersected by trap-dykes, and closely adjoining to the granite, the shock seems to have been felt more severely than anywhere else. The time of its occurrence is stated as 7.45 P.M. Chairs shook; china, windows, and doors rattled; and a dull rumbling sound was heard, which alarmed the inhabitants, as "it was not like thunder." The shock is there estimated to have lasted 15 seconds. At the neighbouring village of South Tawton the sound was heard; but I have not been informed whether any vibration was felt. At Spreyton, also on the Carbonaceous beds, three miles to the N.W. of South Tawton, neither sound nor vibration was perceived. At Okehampton, on the Carbonaceous rocks, the occurrence is described as a kind of rushing sound, or an undulation of sound and motion, considered by the majority of persons as going from east to west; and windows, doors, and chairs were shaken.

On the western side of Dartmoor, at a farm distant about two miles, and "The Fox and Hounds" distant about seven miles, from

Okehampton, on the Tavistock road, on the Carbonaceous rocks near the edge of the granite, similar sensations were noticed. At "The Dartmoor Inn," on the same road, about a mile to the south of "The Fox and Hounds," no motion of the ground was perceived, and the inhabitants attributed a noise heard on the evening of the 28th to distant firing at Plymouth.

Beyond Okehampton and "The Fox and Hounds," I have not been able to trace this earthquake to the west. At Exbourne, four miles to the north of Okehampton, as before mentioned, the earthquake was not felt.

The sound mentioned as being noticed at Druids at seven o'clock on the evening of the 28th may probably be attributed to a distinct shock at an earlier hour on the same evening, as no sound nor motion was noticed in the country intervening between that place and Moreton Hampstead.

With this exception, the shock seems to have been confined to a very narrow district, that may be estimated as not exceeding eight miles in width, and running, as a general direction, at the northerly edge of Dartmoor, along the line of junction of the granite and the altered Carbonaceous rocks. Considering Crediton the most easterly, and "The Fox and Hounds" the most westerly point, the length of the area affected by the earthquake is about twenty-one miles from east to west. The shock seems to have taken a direction from east to west, to have taken place about eight o'clock in the evening, and to have lasted, where most severe, about fifteen seconds.

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## 3. *On some* Veins *of* Granite *in the* Carbonaceous Rocks *on the* North *and* East *of* Dartmoor.

By G. Wareing Ormerod, Esq., M.A., F.G.S.

[Abstract.]

The author referred, in the first place, to the 'Report on the Geology of Cornwall, Devon, and West Somerset,' where Sir H. De la Beche writes (p. 184), "On the north of Dartmoor we find two elvans in the Carbonaceous series, one on the west of Arscot near South Zeal, and the other running through Lidbridge and Lidleigh Ball, on the south-west of Hatherleigh. Dykes of this kind have not hitherto been detected to the east of Dartmoor." He then mentioned the following localities on the north and east of Dartmoor, where the Carbonaceous rocks are intersected by granite- or elvan-dykes. Near Meldon (marked in the Ordnance Map as "Elmdon"), to the south-west of Okehampton, granite-veins penetrate the Carbonaceous rocks near the spot where the white granite was worked. On Cocktree Moor, to the south of North Tawton, he was informed that a granite-vein had been found. The Carbonaceous rocks on both sides of the narrow gorge through which the river Teign passes, after leaving the granite near Chagford, are intersected in many places by these veins.

On the northerly or left bank, on the hill-side above the Logan-stone, a short distance below Hunt's Tor, there is a bed of fragments of Carbonaceous rocks that have fallen from above, and granite-veins occasionally occur amongst these portions, showing that a vein probably exists in that locality. A little lower down the stream turns to the south, and shortly turns again eastwardly. The hill-side from near this last turn to some bold cliffs, known as Sharpy Tor, about a quarter of a mile lower down the valley, is seamed with veins of granite. On account of the depth of soil, and the vegetation, they can rarely be traced for more than a few yards,—they do not appear, except in one case, in the cutting for the walk at the top of the hill,—and they have not been noticed on the north side of the hill or at the Drewsteignton Quarries. The veins throw off branches into the adjoining rock, and vary in thickness from a thin filament to a breadth of about 18 feet. In the small veins the granite is very hard and close-grained; in the 18-feet vein it is of a larger grain, and the felspar is often of considerable size: the veins contain portions from the adjoining Carbonaceous beds, sometimes so slightly removed from the original position that it can be traced; in the large veins some of these masses are rounded, as if they had undergone attrition, but some (about a cubic foot in size) still preserve their angularity. This wide vein is very conspicuous, and can be traced for a considerable distance up the hill-side. The strata adjoining the veins are not contorted or thrown violently out of position by the intrusion of the granite; the displacement would probably not be noticed by a general observer, and presents an appearance such as would be caused by a continuous strong pressure.

Below Sharpy Tor, granite-veins have not been noticed on the left bank of the river. On the right bank at the most northerly part of Whyddon Park near the gate leading into the Moreton Woods, at the turn in the river below the Logan-stone before mentioned, many scattered blocks of Carbonaceous rocks traversed by granite-veins occur; the rocks are not well exposed, and one granite-vein only has been found *in situ*. The depth of the soil and the vegetation prevent the examination of the strata on this bank of the Teign.

To the south of the Teign, two narrow veins of granite, having a direction from N. by E. to S. by W., cross the road from Cranbrook Castle to Fingle Bridge; and a vein of granite, about 19 inches in width, having a direction from N.E. to S.W., in the same vicinity, crosses the road when descending the hill to the west of Cranbrook Farm. The open country to the north of Willistone (about half a mile to the east of Cranbrook Farm) is strewed with blocks of granite and Carbonaceous rocks, the latter for the most part much altered and siliceous, and in these scattered rocks veins of granite occasionally occur; the rocks here are rarely exposed in *situ*, and the places from whence these veins are derived have not been discovered; but there seems to be every probability that they are in the immediate neighbourhood. Mr. Ormerod has not examined the junction of the Carbonaceous beds and the granite further to the south than this point.

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4. *On the* STRUCTURE *of some of the* SILICEOUS NODULES *of the* CHALK. By N. T. WETHERELL, Esq., M.R.C.S.

[Communicated by the President.]

[Abstract.]

THE author described several specimens of the peculiar banded flints* found in the chalk and in gravel, and of which he had made a large collection during several years. They usually exhibit a central longitudinal axis or narrow stem, crossed on its middle third by numerous short parallel stripes of alternately light and dark flint, and frequently terminated at each extremity by an irregular mass of flint, often clouded or grey. The axis occurs sometimes isolated, sometimes covered with a thin coating of grey flint only, and sometimes associated with only a few cross stripes of the banded structure. In some instances the banded flint has for its axis a sponge, or fragments of sponge.

The author had not found in the banded flint any spongy tissue peculiar to it; in some instances, however, a silicified sponge appears to have been traversed by alternate lines of the light and dark colour analogous to those of the banded flints. In some instances a concentric arrangement of light and dark layers of flint occurs around the two ends of an axis, or around isolated nuclei.

Mr. Wetherell regarded this banded appearance in the flint as not being due to an organic structure, but to have originated in a peculiar arrangement of the siliceous matter around organic bodies, frequently long and stem-like, such as those of the *Graphularia*, which supplied so many axial nuclei to the concretions in the London Clay†.

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NOVEMBER 17, 1858.

Augustus Smith, Esq., M.P., 1 Eaton Square, was elected a Fellow.

The following communications were read:—

1. *On some* FOSSILS *from* SOUTH AFRICA. By C. W. STOW, Esq.

[In a Letter to the Assistant-Secretary.]

[Abstract.]

AT the close of 1850 Mr. Stow and his party fell back into the interior to avoid the Kaffirs; in making the journey he collected largely the fossils on his route, and succeeded, with much trouble, in preserving them on his return.

* Mr. Parkinson figures and describes a worn specimen of one of these flints in his 'Organic Remains,' vol. iii. p. 241. pl. 16. fig. 18.

† Quart. Journ. Geol. Soc. vol. xiv. p. 30.

In a plain at the foot of the Rhenosterberg, a branch of the Sneewbergen Range (of which latter the Spitzkop is the culminating point), the author met with patches of ground strewed with nodular concretions and fossil wood (specimens 2 to 63) over an extent of about two miles in length and one in width. These fossils were on the surface, and had been probably derived from the neighbouring mountains.

The plain was of a lozenge-shape, about twelve miles broad and twenty long; and was one of several of a similar kind that he had travelled through. It was bounded by the Rhenosterberg Mountains on the N.E., on the S.W. by a nearly parallel range, and on the S.E. was contracted to a narrow valley between low rocky hills. Two low volcanic dykes crossed the plain, one on the north-western, and the other on the south-eastern side.

The strata forming the mountains are horizontal. There are about eight strata of sandstone forming the lower part of the Rhenosterberg. Immediately above there is a limestone full of rounded fragments of other calcareous and non-calcareous rocks, and sometimes containing bones (specimens 64, 65, 66). Of this pebbly limestone, or calcareous grit, there are four layers, separated one from another by several yards of strata, and varying in thickness from a few inches to about a foot.

The mountains on the opposite side of the plain are apparently composed of the same strata as the Rhenosterberg; for, taking a commanding position on one of the dykes, one can distinctly count the strata in the mountains on either side; and so uniform are they in colour and thickness, so alike in height, and equally horizontal in position, that the idea at once forces itself upon the mind that they must at one time have been continuous.

At one spot on the side of the Rhenosterberg is a Kloof where the author found some fossils imbedded in the rock; and he often regretted when visiting the spot that the Kaffirs had left him nothing but a hammer and old chisel that were thrown into the waggon at starting, as with better tools he might have obtained many more specimens. Here he found the specimens 68, 69, which appear to be casts of stems of plants in sandstone.

The first bones he here discovered were those of the skeleton, specimen No. 83 (a small Dicynodon). They were directly in the water-course, and only a small piece of one part was at first visible. By dint of hammering and chiseling each succeeding portion revealed itself to view. Unfortunately the skull was wanting. Underneath a large part of it there was a whitish scaly appearance on the rock, which might have been the remains of the covering that the animal had when alive.

Many portions of the strata here were matted together with the stem-like fossils, such as specimens 70–75. Specimens 76 to 82 (nodular concretions) appear to have been washed from the same strata.

The specimen No. 125 (leg-bone) was found in the rock a short distance off.

About 20 yards from where the skeleton was imbedded, the specimens 84–87 ("cone-in-cone" clay-stone) occurred. About 30 yards from this spot, and in the same bed, specimens 88 and 89 (bones) were found, where the water ran, and hence the portion at the surface was so softened as to fall to pieces. These pieces appear to show that the ribs and vertebræ are associated with the remains of the animal's outer bony covering or carapace.

Detached from a stratum above the one where Nos. 84–87 occurred, were the two fossil skulls, Nos. 90 and 91 (a small Dicynodon, and a smaller undescribed reptile), and the septaria, Nos. 92 and 93. At a spot a little to the N.W. of the Kloof, and in a bed higher up than the last-mentioned, the nodules and septaria Nos. 94–107 were found.

Between the Kloofs the parting ridges were covered with detached portions of the upper strata, mixed with numerous nodular concretions, such as Nos. 108–114. Some of these contained a fine powder when broken (especially No. 112).

Of the volcanic dykes a few specimens are sent. No. 115 is an exfoliating nodule; and similar concretions are very numerous on both of the dykes, especially on the south-eastern dyke, where they were at some places piled one on another. They varied greatly in size, some being about an ounce in weight, and others too heavy for two or three men to move. This difference of size might be accounted for by the smaller ones having been subjected to exfoliation for a longer period of time. Along the other ridge masses of felspathic trap, such as No. 116, protruded. Many of the pieces were musical when struck—so much so, that some of the people with the waggons, on the first day they arrived, asked what bell it was that was tolling, and which proved afterwards to be some children amusing themselves by striking a large piece of this rock with a stone.

These cross-ridges or dykes attain their greatest altitude towards their centre,—decreasing as they approach the mountains, and then again appearing as exposed precipices or "Krantzes" along their crests.

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## 2. *On some Points in the* Geology *of* South Africa.

By Dr. R. N. Rubidge.

[Communicated by the President.]

[Abstract.]

The author had observed in Namaqualand the occurrence of horizontal siliceous beds, covering other siliceous inclined beds, the silicification of the latter being apparently due to the infiltration of silica from the upper quartzose beds into the inclined beds below. In this communication Dr. Rubidge details the evidences that he observed of such a process having taken place, and points out how the observations on some of the Namaqualand rocks by Mr. Bain, Mr. Bell, and Dr. Atherstone, respectively, tend to support his views

on this point. The inclined beds of this district are gneissic, and, in the instances referred to, very quartzose.

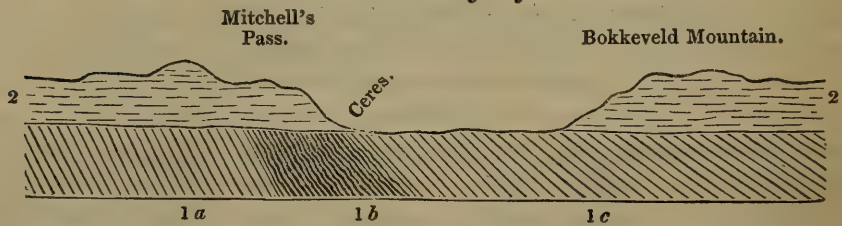
The horizontal sandstones of this district he correlates with the Table Mountain sandstones *; he has found in them a few obscure traces of fucoidal or other plants †.

The author then passes on to the Cape district; and, first offering his testimony to the industry and general exactitude of Mr. Bain as a geologist, he proceeds to compare Mr. Bain's section of Mitchell's Pass ‡ with a section which he lately made for himself on two hasty journeys.

Mr. Bain figures the indurated sandstone or quartzite of Mitchell's Pass as being at first horizontal, and then suddenly dipping at a strong angle northward, so as to underlie the Devonian schists of the Bokkeveld, at Ceres, and to divide them from the slates of the Cape district. Dr. Rubidge points out the apparent difficulty of explaining such an inclination of the quartzite, the slates underlying both the inclined and horizontal portions not presenting any evidence of a difference in dip; and he suggests that the inclined beds of quartzite have nothing to do with the horizontal quartzite, except that, being immediately beneath the horizontal siliceous beds, they have by some means been silicified from above, and thus rendered in appearance identical.

"On referring," says the author, "to Mr. Bain's section No. 1, pl. 21, we see that the Table Mountain Sandstone rests in a horizontal position on the granite and *inclined* slates. Tracing the section westward, we find several alterations of dip in the slate, but no evidence that the more ancient rocks have undergone more than one series of displacements, viz. that which raised the slates of Table Mountain and the Lion's Head to their present position, so that they appear to have remained undisturbed since the deposit of the horizontal rocks. At Bain's Kloof, and at the eastern end of Mitchell's Pass, we find the superjacent quartzite-beds or sandstone still horizontal,—the whole mass being so at its upper part, while its lower beds are highly inclined at an angle conformable with the slates on the one side and the fossiliferous schists of Ceres on the other. (See fig.)

*Section at the Village of Ceres.*




2. Quartzite or sandstone. 1 *c*. Devonian schists of the Bokkeveld.
1 *b*. Quartzose or silicified portion of the schists. 1 *a*. Devonian schists or slates.

* Quart. Journ. Geol. Soc. vol. xii. p. 238; and *ibid.* vol. xiii. p. 235.
† *Loc. cit.* p. 239.
‡ Geol. Trans. 2 ser. vol. vii. pl. 21. fig. 1.

Now, bearing in mind what I have above referred to as having seen in Namaqualand, I at once regarded these inclined quartzites as being the silicified beds of the ancient series, agreeing, like the silicified gneissic beds of Namaqualand, with the ancient rocks in position, and with the superjacent quartz-rocks in lithological character. I was convinced, even in my hasty and imperfect examination, that beds of quartzite, precisely similar to those of Bain's Kloof, &c., rested on, and converted into themselves a portion of the inclined Devonian beds; and that the horizontal beds which Mr. Bain describes as resting on the Devonian rocks of the Bokkeveld, and in characterizing which he uses almost the same terms as in describing the sandstone of Table Mountain, are in reality the same strata, the uppermost of which preserve their horizontal character,—the lowermost having assimilated (by silicification) the subjacent beds to themselves."

Taking this view, Dr. Rubidge considers that the inclined quartzite at Mitchell's Pass is a conformable successional portion of the schists and slates, the horizontal sandstones being of younger age than any of the schistose beds, and extending over them from Table Mountain to Orange River on the west, and to George on the east. On the north the schists are known to be of Devonian age by the fossils of the Bokkeveld; and the recent discovery of a few Trilobites and Spirifers at some spots in the slates of the southern districts of the Cape (near Cape St. Francis, at Klein Winterhoek, and near Jeffery's Bay) is considered by the author as corroborative of his view, that the slates of the Cape are not divisible from the schists of the Bokkeveld, but are to be linked to them by the intercalated quartzites described in this portion of his paper; the schistose rocks of Ceres, Cape Town, and Malmesbury (Silurian and Carboniferous? of Bain) having generally a similar strike and dip.

In the eastern province of the Cape Colony, Dr. Rubidge thinks that a similar condition of silicification exists in the Zuurberg range*, although no overlying horizontal sandstones are there seen. He describes in detail a section made by himself and Mr. R. Pincher, along the road from Port Elizabeth to Somerset, which shows the inclined schistose beds intercalated with a band of dark felspathic rock (the claystone-porphyry of Bain) lying conformably on and passing into the quartzite of the Zuurberg on the south, and, after some great flexures of the quartzites, a similar series of conformable schistose rocks (and a felspathic band) dips from the other side of the Zuurberg in an opposite direction. Similar beds continue with a diminishing dip as far as Van der Merwve's River, whence they rise again to the north to beyond Bushman's River (at Gower's), a little beyond which the felspathic band appears intercalated with them. The section then becomes obscured until the Karoo beds are met with near Brak River, having a slight southerly dip, and probably abutting unconformably against the schists near Callaghan's

* See also 'The Eastern Province Monthly Magazine' (Graham's Town), vol. ii. no. 17 (December 1857), p. 187, &c.

Inn. This section differs in some important features from that published by Mr. Bain of the same district.

Dr. Rubidge considers that the slaty beds flanking Zuurberg on either side, and forming the synclinal trough at the Van der Merwve's River, are of the same age as the quartzites of the Zuurberg, which are in his opinion silicified by metamorphic influences: the interbedded felspathic rock may also in his opinion be possibly of metamorphic origin.

The author follows up his argument by reference to other parallel sections, and regards the plant-beds of Ecca, as well as those of the Great Fish River and the Van der Merwve's River, as being of Devonian age, and not belonging to the lower Karoo beds, regarded by Mr. Bain as having a more southerly extension. Dr. Rubidge notices that some members of the two formations resemble each other so strongly, that sometimes it is difficult to distinguish between them.

The plant-beds above referred to contain innumerable obscure vegetable fragments, like those of stems, reeds, &c.; and in the rocks at Gower's on Bushman's River, Dr. Rubidge has seen, besides fragmentary vegetable remains, some fine jointed stems.

A large series of specimens from the Zuurberg and Van der Merwve's River accompanied this communication; and Dr. Rubidge also sent a series of fossil plants from the Dicynodon- or Karoo-beds of Bloemkop, with which Mr. C. J. Powell, of Graaf Reinett, had supplied him. The plant-beds of the Karoo series, at Bloemkop, contain two or more kinds of *Glossopteris*, very similar to those of the plant-beds of Central India and Bengal.

Amongst the fossils sent by Dr. Rubidge are several fossils from the Zwartzkop and from the mouth of Sunday River; amongst the latter are some *Belemnites* and *Hamites*, probably of Cretaceous age.

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### 3. *On some* Mineral Springs *near* Tehran, Persia.

By the Hon. C. A. Murray, C.B., H.B.M. Envoy Extraordinary and Min. Plen. in Persia.

[In a Letter* to Sir Charles Lyell, F.G.S.]

[Abstract.]

In August the author made an excursion into the wild and rocky valleys of Laridjan, on the northern side of the Elburz chain, to examine some mineral springs near the village of Aske. This village is placed on a steep declivity above the impetuous torrent of the Laur, and is about 40 or 45 miles E.N.E. from Tehran, and near where latitude 36° N. intersects longitude 52° E. It is only a few miles from the lofty and slumbering volcano Demavend†. Round Aske the country is chiefly limestone, with dark-coloured pudding-stone, and

* Dated August 25, 1858.

† For a late account of Demavend, see the paper by Thomson and Kerr in the Roy. Geograph. Soc. Proceed. vol. iii. no. 1.

in several places large tracts of sandy grit, in many precipitous heights of which numerous caves and hermitages have been excavated in olden times.

The most celebrated spring in the neighbourhood is the Ab-i-garm (hot-water),—a warm sulphur-spring that rises on one of the spurs of the Demavend, about six miles to the eastward of Aske, on the left bank of the Laur, and probably about 2000 feet above the bed of that river.

The principal mineral ingredients of this spring are sulphur and naphtha, with some iron and lime. On the 15th of August, the temperature of the atmosphere in the shade, at two P.M., being 75° F., the temperature of the spring at its source was 150° F. From hence it flows down the side of the mountain to a large basin about 15 feet long, 10 broad, and 4 deep, over and around which a large stone bath has been raised. The temperature in the basin is about 118° F. Here in summer thousands congregate from every part of Northern Persia.

The bath seems to be beneficial in rheumatism, neuralgia, and some diseases of the skin.

Formerly there issued from the rock, a few feet from the Ab-i-garm, a cold spring of pure water, which disappeared after an earthquake about forty years ago.

The tepid baths of Aske are about half a mile from the village on the right bank of the Laur, and about 250 or 300 feet above that river. These are used both for bathing and drinking. Lime and carbonic acid gas are abundant in this water. There are several springs of different dimensions, the bathing-basins of which are apart from each other at distances varying from ten to fifteen yards. At half-past five P.M., the temperature of the air in the shade being 71° F., the water in the centre of the largest basin (where the bubbles are thrown up by the gas to an elevation of 6 or 8 inches above the surrounding surface) was at 82°—the average of the temperature of the other springs near by.

On the left bank of the Laur a small bubbling spring of water, similar to those last mentioned, had a temperature of 85° F. These tepid mineral springs lying to the eastward of Aske, do not appear to be affected by the intervention of the deep and rocky bed of the Laur. To the westward of Aske, at the distance of about $1\frac{1}{2}$ mile, on the left bank of the river, and not more than 150 feet above its bed, is a fine cold chalybeate spring: besides iron, this probably contains carbonic acid gas and a small portion of sulphur. Its temperature was found to be 50° F., that of the atmosphere being 73° F. It is not disagreeable to the taste, and in some complaints is found very strengthening and efficacious.

In conclusion, the author referred to the undeveloped riches of the Elburz—its coal, iron, copper, silver, sulphur, marble, and other mineral treasures.

# PROCEEDINGS

OF

# THE GEOLOGICAL SOCIETY.

## POSTPONED PAPERS.

1. *On some of the* Glacial Phænomena *of* Canada *and the* North-eastern Provinces *of the* United States *during the* Drift-Period. By Professor Andrew C. Ramsay, F.R.S., F.G.S., and Local Director of the Geological Survey of Great Britain.

[Read May 12, 1858.]

Contents.



*Glacialized condition of the Laurentine Mountains; and the Drift-deposits of Montreal.*—In the Straits of Bellisle, the barren coast of Labrador consists partly of low patches of red sandstones, &c. lying almost horizontally on the Laurentian series—that most ancient system of gneiss and granite which forms the eastern extremity of the great Laurentine chain. These gneissic rocks are rounded and largely mammillated, as if by the action of ice; and all the distant hills, quite bare of trees, possess the same sweeping contours. The gnarled strata of the lofty Bellisle itself, to the very summit, show unequivocal signs of the same abrasion, their well-worn outcrops presenting none of those jagged outlines that all highly-disturbed beds are apt to assume when exclusively weathered by air, rain, and open frost. Similar forms prevail far up the St. Lawrence, on its north shore, easily distinguishable in spite of the forests which, before we reach the Saguenay, rise to the tops of the mountains, leaving here and there unwooded rocky patches. Further up the river, by the Isle aux Coudres (about 50 miles below Quebec), I became more and more impressed by similar appearances. Not a peak is to be seen; and to the top every hill seemed *moutonnée*. Like much of Wales, Ireland, and the Highlands of Scotland, the country appeared *moulded by ice*.

On the south side of the river the country is low, being formed of Silurian strata chiefly covered with drift from the Laurentine chain; and the vast quantity of boulders and smaller stones that cover the land help to impress on it a poor agricultural character.

Approaching Montreal, the gneissic mountains recede to the north-west; and both banks of the river are low, except where an occasional boss of greenstone pierces the Silurian strata. Montreal Mountain, about a mile behind the city, is one of these, rising boldly out of the terraced drift of the plain.

This drift consists of clay, with Laurentian boulders and boulders of greenstone from the mountain, both mixed with subangular gravels of Utica slate and Trenton limestone, which formations rise on its flanks. Many of the boulders and smaller stones are grooved, or more finely scratched, in a manner undistinguishable from the scratched stones of the British and Alpine drift or of Alpine glaciers. We are indebted to Dr. Dawson of Montreal for three important subdivisions of the superficial deposits,—namely, 1st, at the base, lower boulder-clay and gravel; 2ndly, an unctuous clay, with many marine shells, called by him the "Leda-clay" (*Leda Portlandica*), on which lie, 3rdly, beds of gravel and sand, with shells, one of the most common of which is *Saxicava rugosa*. These subformations occasionally pass into each other where they join. The Saxicava-sand he considers to have been a shallow and sublittoral deposit; the Leda-clay to have been accumulated at depths of from 100 to 300 feet or more; and the true boulder-clay to have been formed at an earlier period of subsidence, during which an ocean spread over the greater part of North America. I shall have occasion to show that at one time this sea was, in places, probably over 3000 feet in depth. The section (fig. 1)* across the drift, which I drew at Montreal, nearly agrees with Dr. Dawson's, with the exception that I show five terraces in the drift, while he gives two. Their number may vary in different localities; but they have certainly been formed during the last emergence of the country, each terrace indicating a pause in elevation; and in a great degree the shells of the upper strata lie in a debris of remodelled drift. The two upper terraces, to the left of Dorchester Street, correspond to Dr. Dawson's Leda-clay and Saxicava-sand.

Between the lowest terrace and the river there is a broad marsh, including patches of recent freshwater shells. It is part of the old course of the St. Lawrence; and on its surface (the lighter drift having been removed) the boulders that once studded the clay have been concentrated. Similar terraces occur on the banks of the Ottawa. The country is strewn with boulders of gneiss and metamorphic limestone, from the neighbouring Laurentine chain, mixed with more local debris; and here also it seemed, in several cases, as if, by removal of the lighter material, the boulders were more concen-

* For the Silurian geology of this diagram, I am indebted to the descriptions of Sir Wm. Logan.

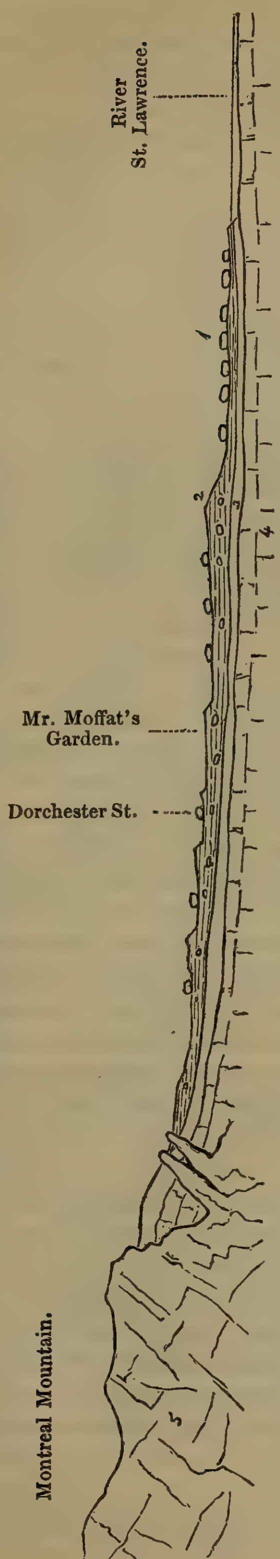


Fig. 1.—*Diagram-section of the Drift-deposits at Montreal.*

1. Marshy ground with concentrated boulders. 2. Drift-beds of clay and boulders, cut into terraces. 3. Utica Slate. 4. Trenton Limestone. 5. Greenstone.

trated on the lower than on the higher terraces. Many of the blocks are rounded; in this respect differing markedly from the majority of those on glaciers, in moraines, and probably from those transported by icebergs, which, derived from glaciers that reach the sea-level, obtain their debris by the fall of rocks and stones on their surfaces from inland cliffs. In the American hills which I saw, there are no signs of true glaciers like those of the Alps having existed; and the boulders have been transported by floating ice from old sea-shores, where they had been long exposed to the washing of the waves.

At Hawksbury Mills I crossed the Ottawa with Sir William Logan, and penetrated part of the Laurentine hills lying several miles from the north bank of the river. Waterworn gravel here and there rises nearly to their summits, now rarely more than 500 or 600 feet above the river.

In the range about eight miles north of the Ottawa, there are well-rounded and occasionally grooved surfaces of gneiss, greenstone, and quartz-rock,—the striations, where I saw them, running 10° and 20° W. of S.

In many places, among the hills, numerous half-rounded boulders (of the same substances as those that strew the plains of the Ottawa and the St. Lawrence) cover the ground, and appear as if they had been waiting their turn for glacial transportation, ere the country was raised above the sea. These general signs existing in this chain, in latitude 45½° N., gave me more perfect confidence in the universal glacial abrasion of the hills on the coast of Labrador in a latitude nearly 150 miles further north.

*Glacial Drift of the Plains; Striæ; and Roches moutonnées.*—I need not indulge in repeated descriptions of the drift that covers the plains of Canada and the northern States. It is enough to say that the descriptions given by previous writers are strictly correct. The whole country is literally covered with drift,—to such an extent, indeed, that, except in denuded water-courses and deep gorges, like those of the Genesee and Niagara, it is only in rare cases that the rock is exposed. Even railway-cuttings rarely penetrate to the rocks below. It may be compared, in Europe, to the northern plains of Germany. In horizontal extension it is the most widely spread of all deposits; and even in thickness it rises to the dignity of a great formation, having by Logan and Hall been estimated in places at 500 and 800 feet in thickness†. In all cases the Laurentian boulders, which have often travelled hundreds of miles, are mixed with fragments of the rocks that crop out northward towards the Laurentine hills, and with stones from the strata of the immediate neighbourhood,—the number of the component materials of the drift thus generally increasing to the south‡, marking the fact that the lowlands as well as the mountains have been subject to the denuding and transporting agency of ice. At a distance from the mountains, the boulders become comparatively few; and it is this admixture of calcareous and other material, often lightened with sand, that fertilizes the soil in the great plains that surround the lakes.

The city of Ottawa stands on Trenton limestone; and the surrounding country is strewn with boulders of Laurentian gneiss and Trenton limestone itself, and of Potsdam sandstone, &c.

Between Ottawa, and Prescott on the St. Lawrence, the basement-rock is rarely seen. The country is chiefly covered with gravel containing boulders of gneiss from the hills, and of Silurian rocks from the plains. Here and there are patches of sand containing pebbles and small boulders, generally rounded. In some places it has the appearance of blown sand,—an effect that may have been produced as the land emerged from the sea.

The shores of Lake Ontario, in general, consist of low and shelving slopes of drift; but at Scarborough bold cliffs of sand, gravel, and clay partly white, with boulders, rise 320 feet above the lake. The terraces of Toronto have been described by Sir Charles Lyell. They are like those of the St. Lawrence and the Ottawa. The lower part of the city stands on a very stiff boulder-clay, containing large and small boulders, many of them scratched. Somewhat higher there are beds of beautifully laminated brick-clays, similar to the clay of the Hudson Valley, afterwards to be described, and probably its equivalent. In 1857, great railway-cuttings were in progress in the lower clay. The terrace marked * in fig. 2 consists of sand, with Laurentian and other boulders resting on white brick-clay, which is beautifully laminated, and in which similar boulders are more sparingly scattered.

The removal of the sand by denudation, to form the terrace, has produced a great concentration of gneissic and other boulders on the surface between the terrace and the lake.

In the great plains between Lakes Ontario, Erie, and Huron, the drift of gravel, sand, and clay, with many large and small striated boulders, is frequently of great

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† I had an opportunity of examining the drift in many places between Quebec and London (which lies between Lake Huron and Lake Erie), about 500 miles from N.E. to S.W. in a direct line, and from north to south between Montreal and Ottawa, to Blossburg and New York.

‡ See Murray's Report, Geological Survey of Canada, 1856.

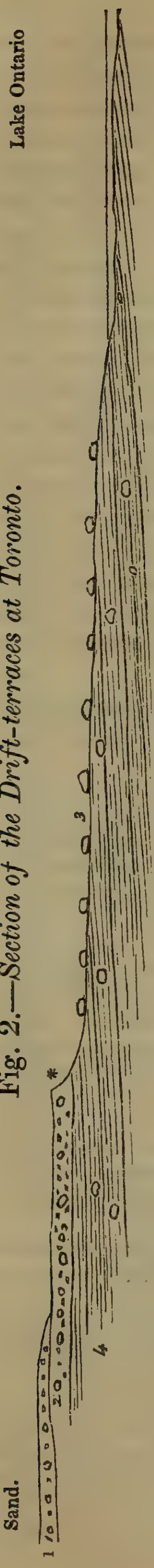



Fig. 2.—*Section of the Drift-terraces at Toronto.*

1. Sand.
2. Sand with boulders.
3. Boulders left after the removal of the sand by denudation.
4. White laminated clay, containing some boulders.

and unknown thickness. White clay occurs round London; from this the bricks are made of which the town is built. The geologist may here travel twenty or thirty miles without seeing rocks in place. In the gravels near Hamilton, elephantine remains were found, supposed by Dr. Dawson to have been washed from the table-land of the Niagara escarpment when the lower plain was still covered by sea.

Between Rochester and Scottsville, the undulating surface consists entirely of drift, containing numerous boulders of Potsdam sandstone, labradorite, gneiss, hypersthene-rock, &c., from the Laurentine Chain about 100 miles off. Many of them are large, smooth, and well striated. Mr. Hall observed that the drift is here often 120 feet thick, and that the mounds are steepest to the north.

The River Genesee runs through a deep rocky ravine, which near Portage is 350 feet high. The rock on the top is smoothed and scratched, and along the whole course of the river, on either side above the gorge, the rocks are generally obscured by drift. On this river Dr. Bigsby observed fragments from Montreal Mountain, which lies 270 miles to the north-east; and Laurentine boulders are common. I observed at Mountmorris, on the river, that in the lower part of the drift the stones are often angular and scratched, while the upper beds are of sand.

Near Portage, on the Genesee, the drift is said by Mr. Hall to be about 500 feet thick, filling up a valley in the rocks, through which an older river ran previous to the drift-period. When the country emerged from the sea, and a new drainage was formed, the river was turned aside by this accumulation, finding it easier to form a new channel in the present gorge, 350 feet deep.

At Onondaga the drift is 640 feet thick.

Drift is equally characteristic of Connecticut and Massachusetts. In the New Red Sandstone Valley of Connecticut, the drift seemed mixed, but mostly local.

It is also well known that large far-transported boulders occur on the south bank of the Ohio,—a circumstance less remarkable than at first sight appears, when we consider that it is stated that icebergs have been seen as far south as the Azores.

Wherever the drift is freshly removed, the rocks are found to be smoothed, striated, and often rounded. On the Isle Perrot, near Montreal, Mr. Billings observed striæ running S.W.; and near Ottawa, by the river, in several places they run south-easterly. These instances are both at low levels; and during a late period it is easy to understand how, during a former extension of the Gulf of St. Lawrence, icebergs drifting up the Gulf, as they do now, would produce scratches running S.W. in the strait between the Laurentine hills and the Mountains of Adirondack, while in the open sea south of Ottawa (now a great plain) the drift passed in an opposite direction. About halfway between Ottawa and Prescott, on the St. Lawrence, near Kempville, the striæ run S. from 5° to 10° E. on a smoothed surface of Calciferous Sand-rock; and at Niagara, on the limestone, S. 30° W., with minor striations crossing each other at various angles. Near Avon, at Conesus Outlet, in the Genesee Valley, on the Corniferous Limestone, the chief striæ run S. 10° W., crossed by many minor scratches, having a general southern course. These crossings might be expected, if the striæ were produced by floating ice subject to minor variations of the currents, and to the influence of winds. The rock is overlaid by clay containing scratched subangular stones. At Genesee, under 6 feet of drift-clay full of scratched stones, the striæ run S. 5° W.; and near Portage, on the top of the gorge, 350 feet deep, the striæ run a little west of south.

The rocks of the St. Lawrence, where it flows from Lake Ontario, deserve more special notice. Above its junction with the Ottawa, the banks of the St. Lawrence are low and shelving, and the rocks are in general obscured by drift; but between Brockville and Lake Ontario, where the river widens and winds amid the intricacies of the Thousand Isles, while the larger islands are partially covered with drift, and well wooded, the lower islets are often only scantily clothed with grass and a few stunted trees and shrubs. Some of them are formed of Laurentian gneiss, and others of Potsdam sandstone. The Potsdam sandstone above the river-bank at Brockville has been ground smooth, and in waving lines passes under the river. The islands formed of Laurentian gneiss or Potsdam sandstone present the same largely mammillated surfaces, rising from the midst of the river, which between Brockville and the lake gradually increases to 9 or 10 miles in width. All of them are *moutonnées*, somewhat like the islands of Loch Lomond; and the surfaces of the little islets often slip under the water quite smooth and unbroken.

This is one of those cases in which it might be contended that the glaciation of these rocks may be due to the floating ice of the river when it breaks up in spring. But though it may produce slight effects, there are several conclusive reasons why the greater features should not be referred to this cause. The old glaciation has passed up the country quite beyond the reach of the present river, while the tops of most of the islands rise far above the extreme height of the water; and again, some of the islands with well-rounded glaciated surfaces present vertical cliffs to the river, sometimes 20 feet in height, where the rocks have split away at the joints; and on these cliffs I observed no sign of that glaciation which we should expect to find if the river-ice exercised any important influence. Further, it was observed by Sir Wm. Logan, that if the smoothing were produced by river-ice, many of the trees of the islets would be shaved off by the yearly ice,—whereas, when untouched by man, they grow to the water's edge. At the only place I landed (a wooding-station), the rock had been too long exposed to the weather to retain its striations; but as we passed the islands, I could see indications of striæ; and it is to be wished that some one would settle the point by determining their exact bearings, the chief directions of which, without presumption, I venture to predict will be *across* the river, and approximately from north to south.

*Drift and Striæ in the Valley of the Hudson, including the Canaan Hills.*—On the banks of the Hudson, south of Albany, the rocks frequently show the familiar mammillated surfaces,—the striations, where I observed them, running nearly north and south. The Highlands of the Hudson also, on a smaller scale, recall the well-rounded outlines of the Laurentine Chain; and at the mouth of the river numerous *moutonnées* surfaces strike the eye, while boulders strew its sides and the surface of Staten Island in the harbour of New York,—all attesting, thus far south, the undiminished energy of glacial action.

Near Boston, gneissic rocks show the same signs; and at Roxburgh, on the outskirts of the city, large surfaces of perfectly *moutonnée* Red Sandstone conglomerate were pointed out to me by Dr. Gould, who informed me that, when he first took Agassiz to the same spot, he at once recognized their ice-smoothed character. The water-worn pebbles of quartz have been ground quite flat on their upper surfaces, and stand slightly out from the rock, the softer sandy matrix of which has yielded to the influence of the weather.

The same kinds of indications are strong in all those parts of Massachusetts, New Hampshire, and Vermont through which I passed. There, as in the other places previously mentioned, the country is much covered with clay, sand, gravel, and boulders, partly rounded and apparently chiefly derived from neighbouring formations. Far-transported boulders may be more scarce among these mountains, their height having partly barred the transport of floating material from the Laurentine Chain, whereas the broad plains south of the lakes were more open to the ice drifting from the north. In the above-named States, instances of fresh and of decaying ice-worn and striated rocks are of constant occurrence in the low ground; and it is truly marvellous to see the same rounded contours rising in the mountains to the very top,—again reminding the traveller of the ice-moulded surfaces of the south-west of Ireland, of the Highlands of Scotland, and of parts of Wales. In none of these American localities are there, however, any signs of pre-existing glaciers, such as are frequent in the mountainous parts of the British Isles.

I am unable to throw any new light on the perplexing question of the glacial phænomena of the Canaan Hills. These have been described by Dr. Hitchcock and Sir Charles Lyell. The range lies on the east side of the Hudson, about twenty miles south-east of Albany, and forms part of the Green Mountains, which are an intermediate part of the long chain that, commencing on the south with the Alleghany Mountains, trends north-easterly to the Mountains of Notre Dame and Gaspé, on the south shore of the Gulf of St. Lawrence. In the district of Canaan and Richmond, their average strike is nearly north and south, the rocks consisting of that part of the Silurian series which ranges between the Birdseye and

Trenton limestones and the Oneida conglomerate,—highly disturbed, cleaved, and partly metamorphosed and foliated. The contours of the hills indicate the moulding effects of ice. The rounded surfaces, wherever they have not been too long exposed to the weather, are grooved and scratched; and these well-defined indications are found alike on the sides and the summits of the hills. In company with Mr. Hall and Sir Wm. Logan, I ascended the Canaan Hills from the N.W., descended into the opposite valley, crossed the Richmond Hills above the Shakers' Village, and, descending into the Richmond Valley, walked to Pittsfield. It is a remarkable circumstance, recorded by Dr. Hitchcock, and partly confirmed by Sir Charles Lyell, and which I also saw, that on both slopes the observed striations run, more or less, *across* the trend of the hills, which at this point strike about N.N.W. The directions of the striæ are between E. 10° S. and S.E.; a larger proportion approaching the first than the second direction. Why they should run *across* the hills and valleys at all has not yet been explained; for, while quite admitting the value of Mr. Darwin's explanation*, it yet does not appear to me to meet a case where the hills are so steep and the valleys so very deep. The difficulty is increased by the fact that the average strike of mountain and valley is from N. to S., which is also the general direction of glacial striations over most of North America; and it is difficult to understand why, if floating ice produced these marks, an exception should have been made in this case, where we might expect the N. and S. run of the submerged valleys would have acted as guides to the icebergs, which would then have floated from north to south as they did in the adjacent valley of the Hudson. The drift is often 40 feet thick and upwards, and is mostly local, many of the boulders being of the Birdseye limestone, which crops out in the valleys. Smaller drift, with these boulders, creeps up the flanks of the hills almost to their summits,—this effect, as stated by Sir Charles Lyell†, having probably been produced in the manner indicated by Mr. Darwin, who, in a similar instance, considers boulders to have been floated up on the ice of successive winters, by little and little during a slow submergence of the country‡.

*The Catskill Mountains.*—On the west side of the Hudson, the Catskill Mountains rise, in their highest peaks, about 3600 feet above

* Phil. Mag. August 1855.

† Proceedings of the Royal Institution, vol. ii. p. 95.

‡ If before the submergence of the country the cold were sufficiently intense, it is possible that each minor range forming the sides of valleys may have been so completely covered with thick snow and ice, that, always pressing downwards from the snow shed, the striations were formed E. and W., or transverse to the trend of the ranges; but in that case both in the valleys and on the sides and summits of the hills, when fairly submerged, we might expect north and south striations formed by the grating of bergs during the deposition of the northern drift. In the case of isolated hills the striæ ought also to radiate from their summits. I observed none of these appearances, but had not sufficient time to search for them in detail. It is clear that the E. and W. striations across the range were not made by a general terrestrial glaciation during, or after, the re-elevation of the country, for then the boulders, &c. transported from low to high levels would all have been swept down again into the hollows.

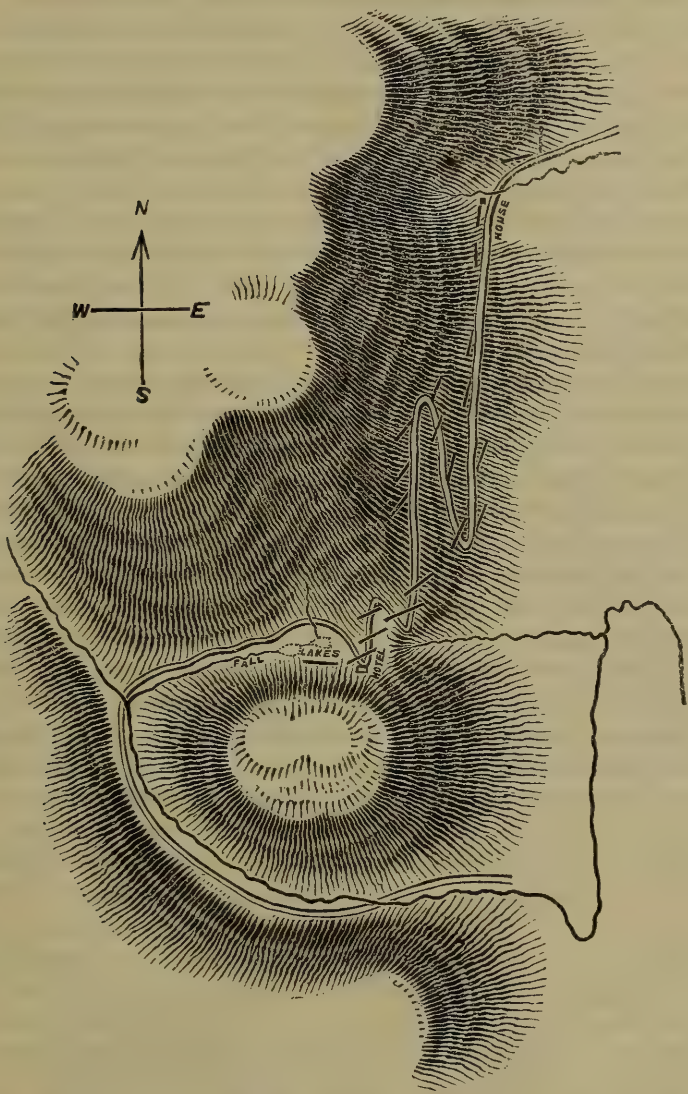
the sea, and nearly that height above the river, which is tidal far above Albany. The strike, both of the Silurian and Devonian rocks of the lower hills, is nearly north and south; and, after traversing a broken country for ten or twelve miles, the Catskill Range itself rises in a long north and south escarpment, nearly 3000 feet above the hilly ground that lies between it and the river. At the town of Catskill, striations on the smoothed surfaces run nearly north and south, following the trend of the Hudson Valley between the Catskill and Green Mountains; and at other points between the river and the mountains they run about N.N.E. I was anxious to discover if on the Catskill Mountains themselves there were any signs of true *glacier-action*, this range being much higher than any other elevations which I had an opportunity of ascending. The low country is as much or even more glaciated than Anglesea; and the mountains are as high as Snowdon; and—though in latitude 42° N., whereas North Wales is in latitude 52° to 53°—other conditions seemed very much the same. Observations also in this region were of more importance, since I am not aware that evidences of any kind of glaciation on these heights had previously been definitely recorded. The accompanying sketch-map (fig. 3), constructed on the spot, will give an idea of the topography of that part of the range which I examined.

I ascended from the mouth of the valley misnamed "Sleepy Hollow," up the steep and winding road to Mountain House. The mountain is almost everywhere covered by dense wood, so that, except on the roadside, it is comparatively rare to find the rocks uncovered. In "Sleepy Hollow" the road runs nearly east and west. Occasionally local drift lies on its steep northern side; and on the smoothed surfaces of rock I observed a few striations from N. to S., and others from E. to W. The former ran up and down the hill towards the brook; and the latter were on the *vertical* faces of the little cliffs, up and down the valley.

Passing the bend where the road crosses the brook, striations became frequent; and I was surprised to find that all of them ran nearly N. and S. along the flanks of the escarpment, and not from W. to E. down the slope of the hill. For a time I thought that as I ascended higher they would cease altogether; but, so far from this being the case, I was alike pleased and astonished to find that they continued equally strong and frequent up to the plateau on which the Hotel stands, 2850 feet above the sea; *and all, but a few of the last, ran not across, but along the face of the escarpment.*

By twenty compass-observations made on clearly defined striations, the chief grooves run between S. 22° E. and S. 55° W. Among these, one runs S. 22° E., two S. 10° E., two N. and S., one S. 10° W., six S. 22° W., one S. 30° W., two S. 55° W., and one W. 10° N. The variations seem somewhat connected with bends and other irregularities in the face of the great escarpment. One of the observations (S. 55° W.) was made on the well-scratched plateau on which the Hotel stands, about 120 feet above the lower part of a gorge which here crosses the watershed towards the lakes, in which the stream rises that, further down, forms the Falls of Catskill. The other is at the bend of the road N.E. of the hotel, near the head of the stream. In the lowest part of the gorge, on the summit

Fig. 3.—*Sketch-map of a portion of the Catskill Mountains, showing the Directions of the Striæ near Mountain House.*



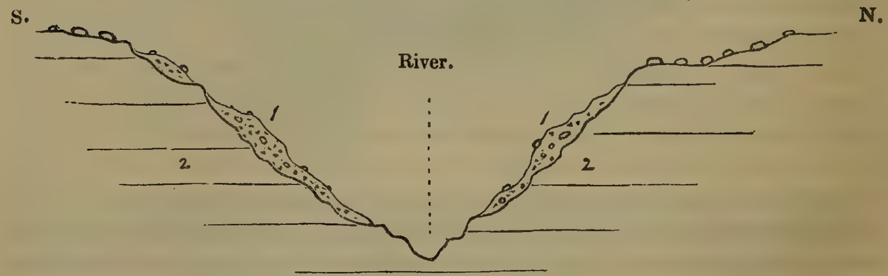

of the watershed, many square yards of smoothed rock are exposed a little off the road; and in this plateau numerous main grooves are seen, passing *across* the hill, and nearly at right angles to most of those observed during the ascent, seemingly pointing to the fact that the icebergs, which striated the eastern flanks of the mountains in a N. and S. direction, when the whole was nearly submerged here found a passage or strait, through which they sometimes floated and grated the bottom in a direction quite across that which they were forced to follow when passing along the great escarpment that now faces the Hudson.

Though the principal grooves run in the directions stated, many minor striations, such as might be expected from floating ice, cross them at various angles.

From this point I made two excursions into the higher parts of the range, in the hope of finding similar markings: but so dense is the forest, that it took two hours to walk a mile; and though in several places the rocks were exposed, they were too much weather-worn to afford all the usual indications. Nevertheless the rounded contours of all the mountain-tops always impressed me with the idea of glacial abrasion; and if, as I believe, they were contoured and striated by floating ice, then the drift-sea of the Hudson Valley was at least 3000 feet deep,—and probably more, if, as is likely, the higher peaks were also submerged. Judging by the general uniformity that seems to have prevailed over North America in changes of level, it would probably be safe to infer that this submergence also extended to the Laurentine and other mountain-chains in the eastern part of North America.

Allowing that the striations on the eastern flank of the great range were made by floating ice, it still does not follow that in the interior there should be no traces of glaciers in the narrow valleys on the opposite watershed,—such glaciers, if they ever existed, being like some of those in North Wales, of later date than the emergence of the country from the drift sea. I had an opportunity of testing this. In the gorge close to the south shore of the little lakes, the striations still run W. 10° N.; and below that point the valley, descending westward from 5° to 10°, is covered with boulders of Catskill sandstone (see fig. 3). About a mile and a half down, at the Falls of Catskill, the valley suddenly deepens; and about two miles further it curves round to the S.E. and S.; and finally the stream escapes from the Catskill Range, and flows towards the Hudson. On either side the valley is bounded by high steep slopes and

Fig. 4.—*Section of the Valley below the Falls of Catskill, showing boulder-drift covering its sides.*




1. Drift. 2. Red Sandstone and Conglomerate.

abrupt cliffs; and the height and form of the ground is such that, under favourable circumstances, it seemed as well adapted for the formation of a glacier as many of the valleys of North Wales, had the conditions for such a result been alike propitious. But the evidence is opposed to any such conclusions. I saw no well-marked *roches moutonnées,* no traces of moraines; and the forest-clad slopes are mostly covered with deep local gravel and boulder-drift, many of the stones in which are scratched. Had a glacier existed there since the drift-period, the drift would have been ploughed out of the valley by the glacier, in the manner that it was removed by the glaciers of the Passes of Llanberis and Nant Francon in North Wales; whereas nothing has been removed, except a portion of the drift by the torrent that now flows in the bottom* (see fig. 4).

*Probable equivalency of the Drift of the Hudson Valley with that of Lake Champlain and of Montreal.*—I have now a few remarks to offer on a part of the drift itself. South of Albany the Hudson flows through a broad valley full of minor undulations, between the Catskill and the Green Mountains. On the banks of the river are extensive beds of sandy clay, from which the bricks are made of which Albany is built. The city stands on this clay, which extends far down the river towards New York, and northward into the Valley of the Mohawk, and as I shall show, probably also into the valley of Lake Champlain. Beyond the river-bank it stretches E. and W. on the undulating ground towards the mountains, rising, six miles in the direction of the Helderberg, far above the level of the river. At its edge, Mr. Hall pointed out to me that the sands, gravels, and boulder-clay of the ordinary drift pass under it. The superficial deposits of the valley of the Hudson, therefore, consist of two subdivisions: first, the older boulder-beds; and, second, the laminated clay, which at Albany is a thick formation, finely and evenly bedded in layers of 1 or 2 inches thick, the argillo-arenaceous laminæ of which graduate into each other in shades of bluish-grey, brown, and brownish-yellow, producing a beautifully ribanded aspect, and giving the impression of a succession of repeated alternations of tranquil depositions in still water. Boulders occur in it rarely; and the top is covered with sand, which may possibly represent the uppermost sandy beds of the St. Lawrence and Ottawa districts. I searched in vain for fossils, both in the paper-like laminæ of clay, and in the abundant concretions, resembling those of the valley of the Ottawa which contain the fossil fish *Mallotus villosus.*

The Hudson runs nearly straight north and south; and forty miles above Albany, at Sandy Hill, the Champlain Canal joins the river to Lake Champlain, which also trends north and south, and, separated by a low watershed, lies in what must be considered a continuation of the valley of the Hudson. The lake is 90 feet above the level of the sea; and on the Vermont shore, 150 feet above the sea, there is a section of six feet and a half of regularly stratified clay and sand, overlying an older blue clay (the older drift), in which were found, by Professor Zadoc Thompson, *Sanguinolaria fusca, Mya arenaria,*

* I was informed by Professor Agassiz, that in the White Mountains, which rise more than 6000 feet above the sea, there are in the higher regions distinct indications of ancient glaciers; and if this be the case, the same phænomena may be looked for in the mountains of Gaspé.

*Saxicava rugosa*, and *Mytilus edulis*, and at the bottom the bones of a Cetacean associated with *S. rugosa* and a *Nucula* or, more probably, *Leda*. The Leda-clay of Dr. Dawson, at Montreal, is also about 120 feet above the river, or 140 feet above the level of the sea. If the so-called "*Nucula*" of Lake Champlain be *Leda Portlandica*, the Montreal beds contain the same assemblage of fossils (except *Sanguinolaria fusca*). In the Montreal beds Sir Wm. Logan also found a number of the caudal vertebræ of a Cetacean. The beds at Green's Creek, Ottawa, containing the same assemblage of shells, *Mallotus villosus*, and remains of Seals, are 118 feet above Lake St. Peter, and 140–150 feet above the sea. Marine shells (*Saxicava rugosa*, *Mya*, *Mytilus edulis*, and *Tellina Grœnlandica*) occur at Kingston, at the entrance to Lake Ontario. Dr. Dawson shows good reason why the above-named fossiliferous deposits on the St. Lawrence and Ottawa should be considered equivalents. In addition, I am of opinion that this conclusion may be extended to the Kingston beds, and that the beds of Lake Champlain leading down to those of the Hudson are of the same date; and if so, then I cannot doubt that the laminated clay that overlies the older boulder-drift of the Hudson Valley is a larger development of the same formation, the whole having been deposited at the close of the drift-period. In that case, a long marine strait filled the valley of the Hudson, and communicated with the sea that, according to Dr. Dawson, then occupied the whole of Lower Canada south of the Laurentine Chain, and, stretching westward, covered the area of Lake Ontario, and washed the great Niagara escarpment which formed its southern coast.

*Probable date of the origin of Niagara Falls.*—It has been shown by Mr. Hall and Sir Charles Lyell, that when the Niagara escarpment rose above the water, the Falls of Niagara began by the drainage of the upper lake-area falling into the sea over the edge of the escarpment above Queenstown and Lewistown. It is not improbable that Lake Erie extended at that period much further towards the present Falls; and, agreeing in the general conclusions of these observers and of Dawson, it follows that, if the sea of the Leda-clay washed the base of the escarpment, *the Falls of Niagara commenced during the deposition of that clay, or a little before the close of the drift-period**. If, with accumulated data, the rate of the past recession of the Falls be actually determinable, we shall then be in a condition approximately to show the actual number of years that have elapsed since the close of the North American drift. It may perhaps appear that the approximate period of 35,000 years, given by Sir Charles Lyell for the erosion of the gorge, is below the reality.

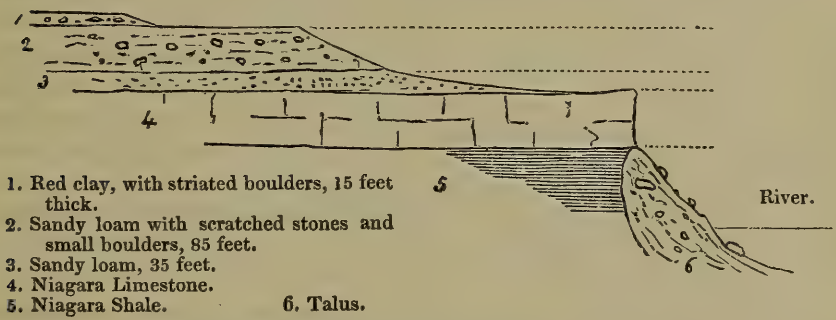
*Drift and other Late Tertiary deposits at Niagara.*—I have little

* It is well known that the Niagara escarpment is of older date than the drift. Lake Erie is 329 feet above Lake Ontario; and the older boulder-drift lies indifferently on the lower plain and on the table-land. No one has yet attempted to show at what period this old coast-cliff, about 400 miles in length, was formed. The upper platform, on a grand scale, bears the same physical relation to the rocks of Lake Ontario that the Oolitic escarpment and table-land in England does to the Lias and plains of New Red Marl below.

to add to the account of the Later Tertiaries of Niagara given by Sir Charles Lyell and Professor Hall.

Above the falls a terrace of drift with boulders forms the left or Canadian bank of the river. Just before reaching the Horse-shoe Fall, the terraced bank recedes; and a plateau of Niagara limestone lies between it and the edge of the gorge. A road, with a deep cutting in the drift, ascends the slope on the left between Table Rock and Clifton House, at right angles to the river. First there is a gentle slope of 35 feet, then a rapid scarped rise of 85 feet, and behind the railway a second low terrace. The first and second slopes, 120 feet high in all, consist of sandy loam (Nos. 3 and 2 in fig. 5), with scratched stones and small boulders; and the upper terrace (No. 1) is formed of 15 feet of red clay, thinly stratified, also containing angular boulders and scratched stones of Laurentian gneiss, and of Niagara limestones and other Silurian rocks. The top of the upper

Fig. 5.—*Section of the Later Tertiary beds near Niagara Falls.*



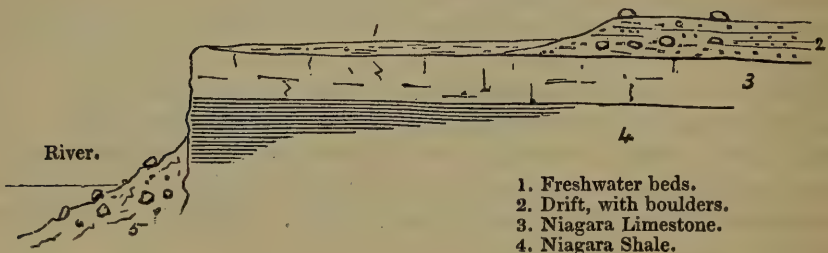

escarpment of drift forms the highest part of the whole plateau. Being 135 feet above the edge of the fall, its top is 60 feet above Lake Erie, which is only 70 feet above that edge. The edge of the great escarpment above Lewiston is said by Mr. Hall to be 70 feet above the top of the fall; and therefore the escarpment No. 1 of the accompanying diagram (fig. 5) is also 65 feet, and No. 2, 50 feet higher than the top of the escarpment above Lewiston, and 45 feet above Lake Erie. If this drift once extended across the space now occupied by the gorge, as shown by the dotted lines, Lake Erie may originally have extended thus far, and after a time the river gradually cut out a channel in the drift and formed both terraces; or else an original terraced channel existed, formed during the emergence of the country, the terraces being formed by marine denudation*.

The lower terrace has, in part at least, been excavated by the river, which, before the formation of the gorge, here spread into a

* It deserves to be stated, that half-way up the cutting, on the surface, I found a *Cyclas*; and another was found by Sir Wm. Logan, with whom I measured the section, on the same terrace, behind Clifton House. Some bits of plate of the "willow-pattern," however, lay near my shell; and that found by Sir Wm. Logan was on ground that had been stirred with the spade; and we came to the conclusion that the evidence they afforded was of very doubtful value.

broad reach, like that above the Falls. It is on a continuation of this platform, about a quarter of a mile below Clifton House, between the drift-terrace and the edge of the gorge, that the strata containing existing river-shells occur (fig. 6).

Fig. 6.—*Section showing the position of the Freshwater beds above the Gorge of the Niagara.*




This drift-terrace Sir Charles Lyell has shown to be as old as the Mastodon-period. The freshwater beds lie in a shallow hollow on the limestone. They consist of remodelled drift, and some of the stones are scratched; but whether the scratches made in the older drift-period have not been worn away, or whether the stones were scratched by river-ice is uncertain. The floor of Niagara limestone is here deeply furrowed, the striations and minor scratches crossing each other at various angles; but the majority run S. 30° W. They follow the general direction of the other striations of the country, that underlie the drift.

On Goat Island, Sir Wm. Logan and I observed that the fluviatile strata lie on drift,—a circumstance, I believe, not previously noticed. It consists, at the base, of sand; and above, of clay horizontally and evenly bedded, containing scratched stones and boulders. As shown in Sir Charles Lyell's diagram*, at the eastern end of the island the Niagara limestone rises a few feet above the river, in the still recesses of which are numerous living shell-fish. Between this point and the summit of the island overlooking the Falls, there is a gradual fall of 15 feet, showing the slope of the river-bed when Goat Island was covered with water. The drift at this point is 29 feet thick, and the freshwater beds above 10 feet, giving 39 feet for the height of the island above the water at the edge of the Falls. Allowing a dip of 25 feet in a mile for the general dip of the limestone, Goat Island was covered with water when the Falls were probably about one mile and a half further down than at present. With regard to the retrocession of the fall, as might be expected, its rate is fastest when the body of falling water is greatest, this cause of waste being far more powerful than the winter's frost. Towards the base of the edges of the Horse-shoe Fall, and at the American Fall, blocks of limestone are accumulated in great heaps, while in the middle of the Horse-shoe Fall the turmoil is so great that it scoops

* Travels in North America, vol. i. p. 37.

out the shale beneath so deeply that the great fallen blocks are lost in the abyss. Where the body of water is small in the American Fall, the edge has only receded a few yards (where most eroded), during the time that the Canadian Fall has receded from the north corner of Goat Island to the innermost curve of the Horse-shoe Fall.

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## *On the* Westward Extension *of the* Old Raised Beach *of* Brighton; *and on the Extent of the* Sea-bed *of the same Period.*

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

[Read May 26, 1858.]

This raised beach, with its curious old sea-cliff brought to light again in the modern cliffs at Kemp Town, was first made known by the late Dr. Mantell*. Mr. Dixon† afterwards showed that beds of the same age extended to Shoreham and Broadwater, near Worthing; whilst Mr. Godwin-Austen‡ has more recently described, on the coast between Bognor and Bracklesham, two thin marine beds of Newer Tertiary age, the uppermost of which he considers synchronous with the raised beach of Brighton§. The exact range westward and inland of this old beach, or of the sea-deposits of the same age, has not, however, yet been determined. With a view to assist this inquiry, I beg to lay before the Society the facts having reference to it which I have collected during the last few years, whilst examining the Older Tertiary strata and the drift-beds of this district,—the result, however, more particularly of two excursions made with the special view of tracing, if possible, the line of old cliff along the southern base of the South Downs between Brighton and Portsmouth. On the present occasion I do not propose to touch upon the question of the drift||, beyond describing such portions of it as are exhibited in conjunction with the older sea-bed. I may merely observe that the drift which has passed over this district has so swamped and hidden even its later geological features, that in a distance of thirty-seven miles I could not find a single place where an old line of cliff, such as that at Kemp Town, could be recognized by any irregularity of surface, although I have, in several instances, traced the sea-bed and shingle of that period to within a few hundred feet of the chalk-hills. There is, in fact, nothing in the present features of the country to indicate the exact place of the old coast-line.

At Brighton the line of old chalk-cliff ranges probably nearly parallel to, and not far distant from, the present shore, receding rather further at Hove, but nowhere, between Brighton and Shoreham, extending above half a mile from the present coast. Between Hove and Shoreham a bed of sand and shingle with recent shells,

* The Fossils of the South Downs, &c., p. 277.

† Dixon's Geology and Fossils of Sussex, p. 40.

‡ Quart. Journ. Geol. Soc. vol. xiii. p. 62.

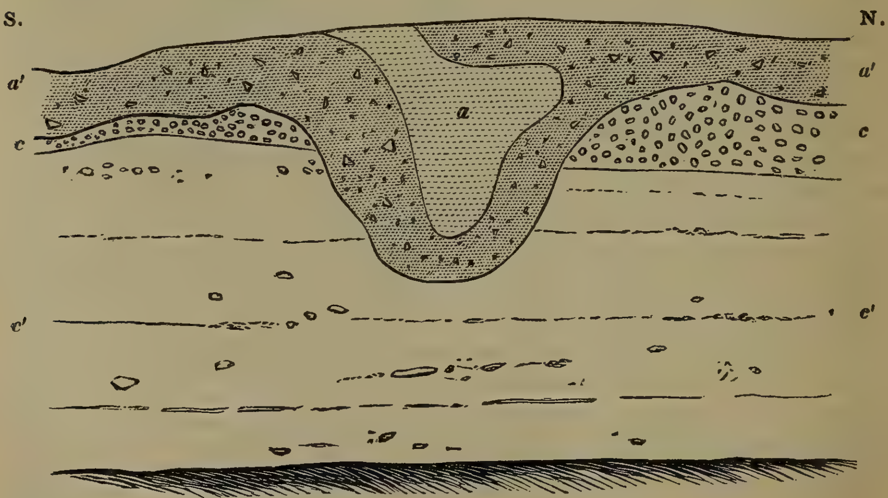
§ See also the observations of Sir R. Murchison on this beach and on the overlying drift, Quart. Journ. Geol. Soc. vol. vii. p. 364–372.

|| See the papers by Sir R. Murchison and Mr. Godwin-Austen on this subject.

underlying chalk-rubble and gravel, has been traced near the present shore by Mr. Dixon; but further inland the drift hides the substrata, until the chalk-hills rise bare from beneath it. The same features prevail yet further westward, but with a greater width of the old sea-ground. Mr. Dixon gives sections at Lancing, Sompting, and Broadwater, proving the existence at these points of the same sand and shingle, with sea-shells, under subangular drift, at a distance of 1 to 1½ mile inland, and near to the base of the chalk-hills.

Between Broadwater and Arundel, I was unable to find any clear section of this deposit, although there are, I consider, traces of it to be seen in the presence of rounded shingle at slight elevations to the E. and S.E. of Arundel, and at a distance of three to four miles from the sea. In proceeding westward from Arundel this sea-bed becomes, owing to the greater height and more broken nature of the ground, much more distinct, and can be followed, with little difficulty and with but slight breaks, to beyond Chichester. The first place where I found it exposed was in a pit in the wood on the north side of the high-road from Arundel, and exactly two miles due west from Arundel Castle. It there puts on the form of a bed of sand about 6 to 8 feet thick, and is overlaid by subangular flint-gravel. This sand contains no fossils, and is so much like some Tertiary sands that it might almost pass for them. It contains, however, thin patches of worn shingle, and a few rolled beach-formed pebbles, which afforded some slight grounds for separating them from the Eocene mottled clays on which they repose. The ground continues to rise gently, and on the brow of the hill looking down into

Fig. 1.—*Section of the Sand-pit north of Avisford Bridge.*



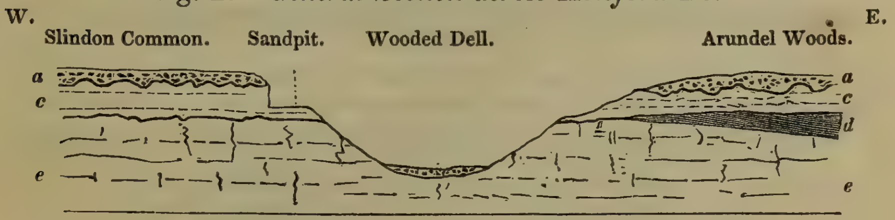

| | | feet. | feet. |
|---|---|---|---|
| *a*. | Brick-earth, forming the core of gravel-furrow or pipe ...... | 10 by | 8 |
| *a'*. | Dark ferruginous sandy clay, full of large angular flints ... | 5 to | 6 |
| *c*. | Worn and partly-rounded flint-shingle in dark clay ......... | 3 to | 4 |
| *c'*. | Fine sand, with a few thin seams of shingle, and some rough flint-pebbles ............................................ | 16 | |

the pleasant wooded dell which runs at right angles to the road at

Avisford and trends away northward to the Chalk Downs, we find the subangular flint-gravel overlying the same bed of sand, with the mottled clays cropping out from beneath. Following the dell northward for a distance of five furlongs from the high-road, I found, on its west slope, a sand-pit (fig. 1) which afforded a far better section than I had hitherto met with.

The base of the sand is not seen in this pit; but the chalk crops out at a short distance, and at a level not many feet lower. The sand is light-coloured, siliceous, and roughly bedded, and contains a few thin seams of fine, worn shingle and a few dispersed rolled and worn flints—also traces of carbonaceous matter, but without a trace of any shells that I could discover. On the top of this sand is a bed, *c*, 3 to 4 feet thick, consisting of closely-compacted flint-pebbles chiefly of one size—about that of an egg. Although well worn, they are, unlike the smooth and regular Tertiary pebbles, only roughly rounded —just such as we should now find on an exposed shore. The interstices between the flints are filled by clay like that of the drift above, and seemingly without any fossils. Irregularly spread on the old shingle is a dark ferruginous clay-drift, *a*, full of large and small, sharply angular, and unworn flints, with, here and there, a worn pebble caught up from the shingle beneath. But the important feature of this section is the height to which this old sea-bed here rises above the present sea-level, and the fact of its intersection by one of the existing system of valleys. By observation with an aneroid barometer, I should estimate its height above the sea to be about 80 to 100 feet. The dell, near the brow of which it is situated, commences on the higher part of the Downs, where it is known as the Fair Mile Bottom, passes by Dale Park and Avisford, and joins, at Binsted, the great flat plain of the coast. The gravel and sand are found on both sides of the dell for a distance of about three-quarters of a mile above Avisford, ending at a short distance from the above sand-pit. (See fig. 2.)

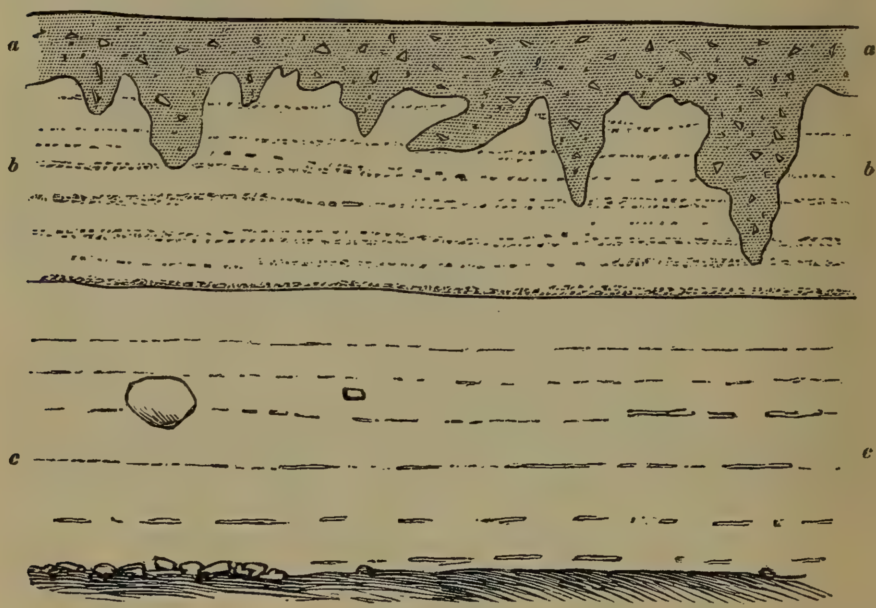
Fig. 2.—*General Section across Avisford Dell.*




*a*. Angular flint-drift, passing into subangular gravel.
*c*. Sand and worn shingle.—Old sea-bed.
*d*. Lower Tertiary Mottled Clays.
*e*. Chalk.

Slindon Common, immediately west of this sandpit, is everywhere covered by the same gravel, which is, I am informed, underlaid by sands. The latter are not, however, at present exposed in any section; but in a pit on the west side of Slindon Bottom, which runs parallel to, and 1½ mile west of, Avisford Dell, the subangular gravel and underlying light yellow siliceous sands are again exhibited. The shingle-bed is here wanting; and the sand-bed *, which is on a rather lower level than at the first pit, is still without traces of shells. I also found small sandpits in a wood at the corner of two roads between Hungerdown and Eartham, and again near Boxgrove Common, and thence traces of the same sands are apparent at intervals as far as Goodwood. At the entrance to the Park there is a large sandpit in a small copse by the road-side. My attention was first directed to this very interesting section by Mr. H. W. Bristow. The sands are here so fine and so regularly stratified as to look more like some Older Tertiary sands rather than any of our hitherto known Post-pliocene beds. This pit is 6½ miles distant in a straight line from the nearest part of the present coast. The following sketch represents its chief features.

Fig. 3.—*Waterbeach Sandpit at the S.E. corner of Goodwood Park.*




*a*. Bright ferruginous clay, full of large and small angular flints; furrowed and worn into the underlying bed ...... 2 to 6 feet.
*b*. Whitish chalk-rubble with irregular seams and layers of small angular fragments of flint and small gravel ......... 8 to 10 feet.
*c*. Very fine light-coloured and slightly micaceous sand, with patches of shell-sand, and a few subordinate layers of thin, very hard, rough, tabular sandstone, and a few rare chalk-boulders. Some shells, in a very friable condition, are irregularly dispersed through the sand ..................... 14 feet.

The upper drift "*a*" is like that at the Avisford pit, but the bed of shore-shingle is wanting here. We find, on the contrary, under the ferruginous clay-drift, and deeply indented by it, a roughly-stratified white drift of chalk and flint-rubble, *b*, like that imme-

* I am informed by Mr. Martin, of Pulborough, that similar sands have formerly been worked at Ball's Hutt, on the high-road near this place.

diately overlying the old beach at Brighton. I did not, however, find here any organic remains in either of the drift-beds. Beneath them is a deposit, the upper 2 or 3 feet of which consist of a slightly argillaceous and laminated sand, and the lower part of a pure fine sand, with a few patches of rather coarse shell-sand, and here and there a well-worn flint-pebble (like a beach-pebble). Some thin seams of the sand are concreted, forming very hard, thin, tabular sandstones, sometimes curiously covered with innumerable, small, blunt, projecting points. These concretions are more numerous and thicker in the lower part of the pit; and they form so hard a floor, that a man, whom I employed to dig down to the chalk, was not able to do so during my stay there. At first sight these sands appear unfossiliferous, but a short search shows the presence of a number of minute and very friable shells from $\frac{1}{4}$ to $\frac{1}{2}$ inch long, and which proved to be the young, apparently, of the common Mussel. I also found a few full-grown specimens of this shell and of the common edible Cockle; but they all fell to pieces when touched. On a second visit I was, however, fortunate enough to discover a few other shells preserved undecayed in a singular way. In looking over the pieces of tabular sandstones thrown on one side, I found one, and then another, angular block of hard white chalk (like the hard chalk of Yorkshire), that evidently had come out of the sand, some of the latter yet remaining in hollows in the blocks, and some portion being concreted on them in lumps.

These blocks, which are respectively $1\frac{1}{2}$ and 1 foot long, are covered on three sides with holes made by boring molluscs, probably the *Pholas dactylus*, and by small Annelid-borings*. In some of the larger of these holes I found a few uninjured specimens of the *Purpura lapillus*, whilst some others were attached, as when living, to the outer surface of the blocks, together with numerous small *Balani*, probably the *B. porcatus*. On looking further in the sand-bed itself, I observed at "*y*" another and larger block of hard chalk, the projecting portion of which measured six feet in circumference; but it was much more worn and rounded than the other two, and I could see no shells attached on the exposed portion.

Owing to the extremely friable condition of the greater portion of the fossils, I have at present not been able to determine, with Mr. Morris's assistance, more than the few following species:—

| | |
|---|---|
| Mytilus edulis, | Purpura lapillus, |
| Cardium edule, | Balanus porcatus, |
| Pholas dactylus ?, | Echinocyamus pusillus; |

whilst in a small quantity of the sand which Mr. Rupert Jones and Mr. W. Parker kindly examined for me, they discovered the following species of *Foraminifera*, which, like the shells, are all of common recent forms:—

Nonionina asterigerina, Rosalina Beccarii, Truncatula lobatula.

Of the little Green-pea Urchin (*Echinocyamus pusillus*) I found only

* Just such masses as may be picked up at the foot of our present chalk-cliffs.

one specimen. Of the other fossils I obtained several specimens,—the bivalve shells being common, but extremely difficult to preserve entire*. The *Purpura* and *Balanus* I found only on the blocks of chalk; and I should be disposed to infer, from the condition of the Bivalve Molluscs, *Foraminifera*, and *Echinodermata*, that they lived on the spot—probably a sandy-bottomed, sheltered bay of some moderate depth of water,—and that the chalk-boulders with their attached fossils were transported from some adjacent line of chalk-escarped coast, and quietly dropped at a short distance from the shore. As almost all the above species have a considerable range in time, it will require a larger collection of organic remains to determine the exact age of this deposit: that it is comparatively very recent, probably Post-pliocene, there can, however, be little doubt; nor is there, I think, much doubt of its synchronism with the old Brighton beach, or rather that these sand-beds are the seaward prolongation of the old beach. The cliffs, if cliffs there were, are swamped and hidden by the overlying drift, as the old cliff is at Kemp Town †.

Westward from Goodwood the sands may be traced a short distance towards Lavant; but, beyond that place, at East Ashling, Funtingdon, and Racton, I could not obtain any satisfactory proof of their presence. Taking, however, the road from Aldsworth westward over Bourne Common, there is, on the top of the low hill overlooking the reservoir, a gravel-pit opened in a bed of flint-shingle, closely resembling, though not so large as, that of the old beach at Avisford Dell; but there is no drift above it, and no sands were exposed under it. Thence to Leigh and Havant, three miles further westward, I met with no other sufficient sections. Still further westward and southward, beds, apparently of this age, have been described by Mr. Godwin-Austen in a series of excellent papers published in the Journal of this Society. I would more particularly refer to the raised shingle which he mentions near Portsmouth, to the great shingle-cliff at Bembridge in the Isle of Wight,

* Mr. Hills, of the Chichester Museum, showed me some perfect specimens of the *Mytilus edulis*, *Cardium edule*, and *Tellina Balthica*, which he had found in a bed of sand by the side of the railway at Oving, three miles east of Chichester. He has also found in the lower part of the gravel at Port Field, near Chichester, some irregular thin seams of chalky marl containing land and freshwater shells of the following species:—

| | |
|---|---|
| Helix hispida. | Pupa marginata. |
| —— nemoralis. | Planorbis spirorbis. |
| Succinea putris. | Bulimus obscurus. |

† Remains of shells have been found in the raised beach at Brighton, but they are very scarce. Dr. Mantell also obtained from it a bone of the Whale (*Balæna mysticetus*). Mr. Dixon mentions *Littorina rudis* and *L. neritoides*, *Purpura lapillus*, and *Mytilus edulis* from the Post-pliocene sand and shingle of Shoreham and Broadwater. He also gives a long list of shells (*op. cit.* p. 17) occurring in an old sea-bed at Bracklesham Bay and Selsea, which he seems to consider more recent than the Brighton bed; but he does not assign his reasons for that opinion. Sir R. Murchison likewise found shells beneath the "angular flint-drift" at Hove (*op. cit.*).

and to a shingle which he describes under the gravel at Cowes. I cannot, however, do better than refer the reader to the several papers themselves, as they abound in information connected with this and many collateral subjects*.

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## *On the* Lacustrine *or* Karéwah Deposits *of* Kashmere.

By H. Haversham Godwin-Austen, Capt. H.M. 24th Regt., Kashmere Survey.

[In Letters, dated May—October, 1857, and February, 1858, to R. A. Godwin-Austen, Esq., F.G.S.]

(Read June 23, 1858.)

There is a point of geological interest at a place called Kuttai (on the River Jhelum, going up to Baramula), where the surface is covered with enormous granite-boulders. At a march and a half (22 miles) further on, they occur again, at a place called Oorie, and extend up the valley, past a place called Gingle, about 12 miles. Vigne notices this place (Oorie) in his 'Travels'†. The hills at Kuttai are of limestone, and at Gingle of a basaltic rock. Mr. Vigne says,—"I know of no granite in Kashmere except in Hara-mook, but not *in situ*. Hara-mook rises opposite the entrance to the Baramula Pass ‡; and the same medium must have *floated* or *forced* the granite of Deotsuh to either place from the northward." This passage in Mr. Vigne's work has given rise to the notion that glaciers from Hara-mook once extended across the valley of Kashmere. If this had been the case, it seems to me that some few blocks or boulders would be found scattered across the valley, and left at various heights on the slopes above the river (Jhelum). Such, however, is not the case: the granite-blocks on the surface at Kuttai, Oorie, and Gingle are never higher than the level of the "alluvial" plain; and these are found through the whole thickness of the alluvium from top to bottom; as may be seen in the sections, when the nullahs cut through it.

The following plans and sketches (figs. 1, 2, and 3), taken along the Jhelum, will show the character of the deposit, and its position at the places named, beginning with Kuttai.

The river at Kuttai is very rapid. The dotted part in fig. 1 is that covered with granite-boulders, and has a breadth of 2½ miles. It is limited by the Jhelum on the south, which has cut through its entire thickness, and by a torrent, which discharges into the Jhelum from the north (*a*). The cliffs at *b* are nearly 200 feet high. The torrent from the north has the alluvial beds on the left, and the base

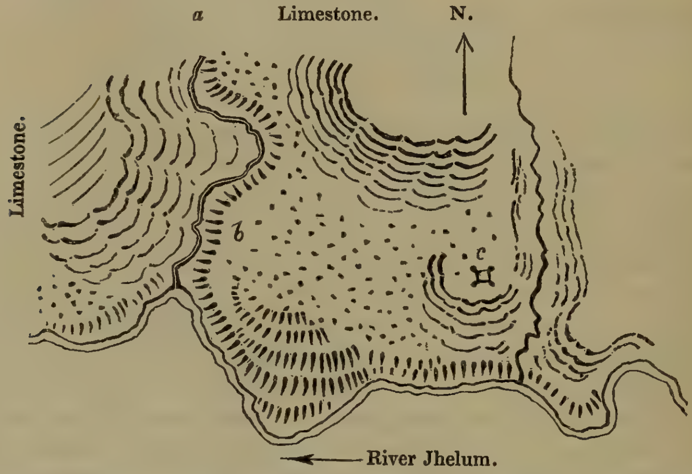
* Quart. Journ. Geol. Soc. vol. vi. p. 69; vol. vii. pp. 118 & 278; vol. xi. p. 282; and vol. xiii. p. 40.

† Vol. i. p. 278–279.

‡ Mr. Vigne (p. 283–4) supposes that the Baramula Pass was produced by a great rent, at which time it was choked by the mass of alluvium now found there.

of lofty limestone hills on the right. Fig. 2 is a section across the alluvial beds from the Fort of Kuttai to the torrent, which, as well as another on the other side of the fort, comes down from the north (see fig. 1). What is to be seen here and at the other places seems to me to upset Mr. Vigne's hypothesis; and all that I now want to find out is the composition of the Snowy Range to the North. The sketch, fig. 3, represents the valley from Gingle to Oorie.

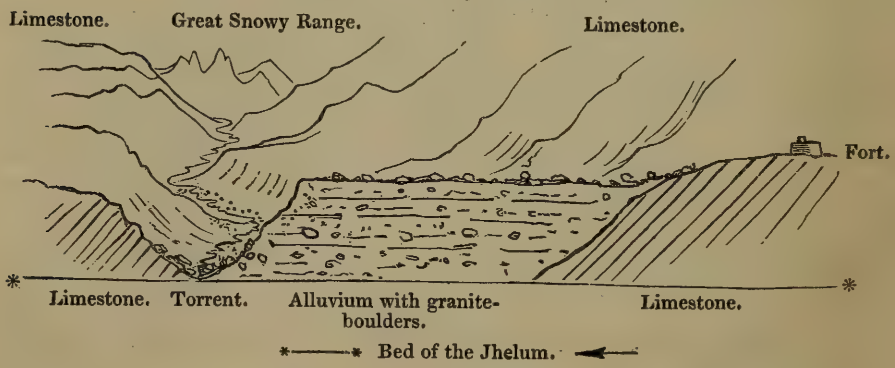
Fig. 1.—*Sketch-plan of the Alluvium in the Jhelum Valley near Kuttai.*




About twelve miles north of *a* is the Great Snowy Range. The cliffs at *b* are about 200 feet high. *c*. Kuttai Fort. From *b* to *c*, about 2½ miles. The dotted portion is covered with granite-boulders.

At Oorie, where occurs the next accumulation of granite-boulders, the valley or gorge of the Jhelum widens out at the junction of a valley from Poonch on the south. The Fort stands on the alluvial

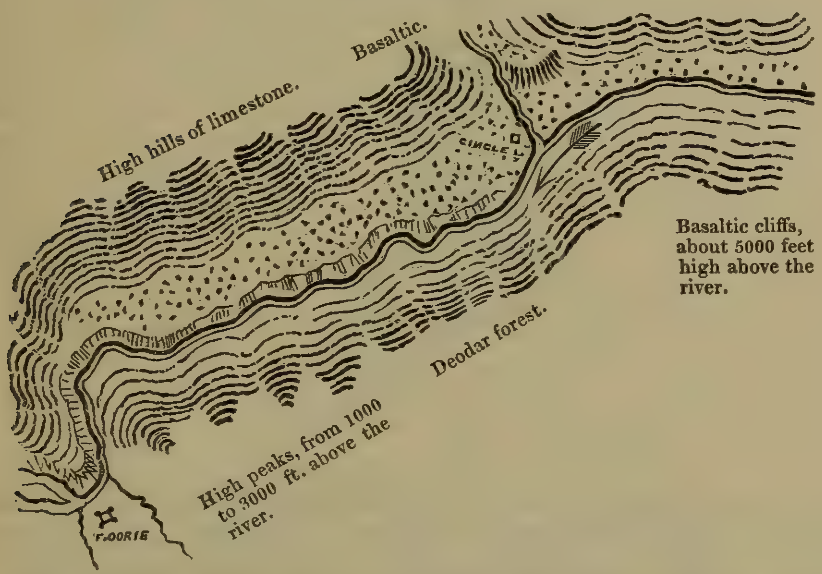
Fig. 2.—*Section of the Alluvium cut through by the Torrent North-west of Kuttai.*




plain, as shown in fig. 3, and the Jhelum flows in a deep channel which it has cut through the alluvium. If the granite-boulders had been conveyed from beyond Hara-mook as far down as Kuttai, they should be met with in the interval between that place and Oorie, but such is not the case.

Cliffs of the "alluvial" gravel form the north bank of the Jhelum from Oorie to Gingle, there being a narrow level band of this accumulation running the whole way between these two places, along the base of the lofty limestone range on the north; on the south the peaks rise from 1000 to 3000 feet above the river, and are covered with Deodars (fig. 3).

Fig. 3.—*Sketch-plan of the Alluvium on the Jhelum between Gingle and Oorie.*




The Jhelum and the torrents which discharge themselves into it have cut down their channels so as to have one bank composed of the alluvium, and the other of the fundamental rock. With the exception of the granite at Kuttai, Ooorie, and Gingle, the fragments of rock in the alluvium are such as are to be found on the sides of the valley, namely, limestone or trappean rock, with great quantities of fine earthy matter. For this reason I cannot agree with Mr. Vigne, that the "alluvium" of the gorge of the Jhelum was carried and deposited there at the time when (as he supposes) the break of the strata at the Baramula gorge took place.

The fort at Gingle is situated in the alluvial plain or platform. Here, as at Kuttai, a torrent comes down from the north; the valley expands, and is occupied with the alluvial deposit. An old line of cliff may be here observed in the alluvium, separated by a second level from the present bed of the Jhelum.

The upper surface of the alluvium is a perfect level, as if the Baramula gorge had been filled with water, forming small lakes at Gingle, Oorie, and Kuttai; and it seems to me that the whole of the alluvium was accumulated before the river began to cut down its way to the level at which it now escapes.

In descending a slope of the Karéwah Hills, near Manganwar, I came upon what seemed to me to be both curious and interesting in many ways, more particularly as showing the manner and extent to which the surface of this formation (the lacustrine deposit forming the Karéwahs) has been lowered and reduced. The sketch, fig. 4,

Fig. 4.—*Perched Block, on a pillar of clay, on the side of the Karéwah Hills, near Manganwar.*

which will describe it better than words, represents an enormous block of stone (of the kind of igneous rock to be met with in the higher range) resting on a column of hard clay, about 8 feet in height. The clay, with pieces of rock, mostly angular, is the same with that which forms the mass of these Karéwah Hills, and all the materials of which hills *have been washed down from the higher ranges above them.*

The lowering of the surface, except when it was protected by a block of stone, must have been owing to heavy vertical rain-falls; nothing else could have left rocks so perched and isolated. This process is not going on now. The surface of the soil is protected by a covering of vegetation (Deodars); and the particular block here represented must have been in its present position for an enormous length of time, as a tall Deodar has grown up alongside, so that the block seems to rest against it*.

"Karéwah" is the Kashmere name for these low alluvial hills, some of them 200 feet in height, and very steep, with small streams (not so large as ours at Chilworth) bubbling along the valleys, which here and there open out to 300 yards or so in width; at these spots

* Mr. Vigne notices what I fancy must be the same thing (see his work, p. 285, vol. i.):—"The valley of the Gurys contains a great mass of alluvium at its north end, and in that of Iskard there is a vast quantity of muddy deposits worn into banks, hollows, and pinnacles."

are small villages buried in walnut, apple, pear, and cherry trees; the first of these becomes a magnificent tree here.

*West Watershed of Kashmere, at the Kūkur-gulli.*—Another day my work lay along a high ridge of the "alluvium" rising from 200 to 300 feet above the river. The alluvial accumulation rests on the limestone, and the river (Kahmil) has cut through the whole thickness of the alluvium, and as much as from 30 to 40 feet into the limestone beneath.

The "alluvium" here consists of rocks of all descriptions, derived from the higher range, and amongst them are a few blocks of granite; all are water-worn, more or less. The same formation occurs lower down (about 1½ mile), where the river, after passing through a very narrow gorge, debouches into the plain; thence the bank of alluvium runs perfectly straight for 3 miles, rising from the plain as much as 100 feet. At the edge, near the top, there is a regular roadway, about 30 yards in breadth; then another rise of about 20 feet, with a perfectly level plain at the top,—the bed of the lake which, there is no doubt, at one time occupied the whole valley of Kashmere.

Fig. 5.—*Plan of the Terraces in the Valley of the Kahmil.*

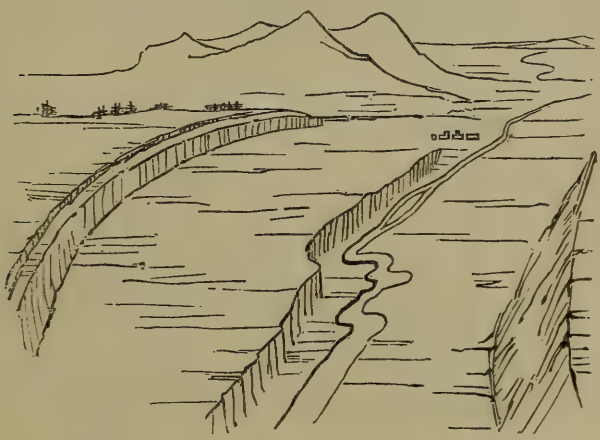
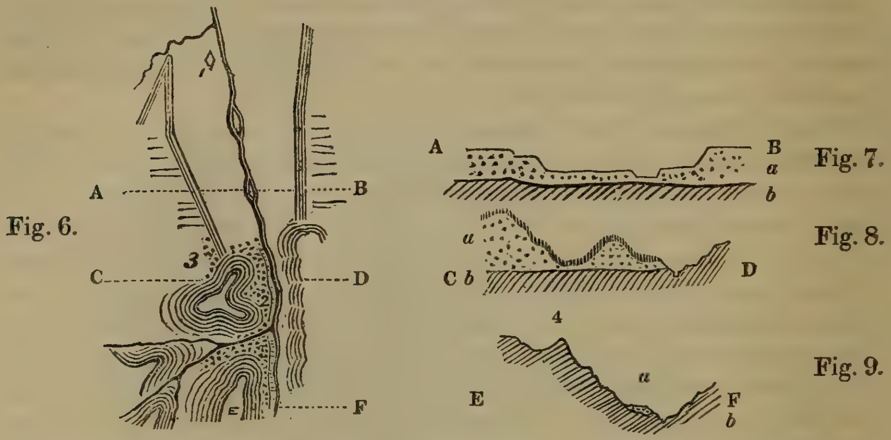


Fig. 5 is a bird's-eye view of these terraces, as seen looking down the river towards Shaloorah. The Hod River joins the Kahmil in a like depression. I have not exaggerated the straightness of the edge of the bank in the least. The roadway (or upper terrace) was not broken down for the whole distance. The valley has evidently been lowered at several successive stages, and at each level the breadth of the water has been less.

On the Kukur, I found a snail (*Helix*) such as I had never seen, and the only one in fact which I have ever met with on these hills. I have preserved it for transmission home with the plants. These animals must be rare in the higher ranges, or I must have observed them. I may also mention, that in all my wanderings amongst the

Karéwah Hills, I never was able to find the slightest trace of a land or freshwater shell in any of the many sections I have examined.

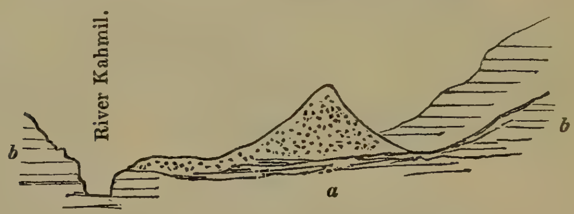
Figs. 6–9.—*Plan and Sections of the Kahmil Valley.*




1. Shaloorah. 2. Roodi. 3. Makām. 4. Kachdab. *a.* Alluvium. *b.* Limestone.

*Snowy Range; North Pingal. Kaj Nag,* 14,407 feet.—From some cause or other (local attraction) the compass would not act at this end of the ridge. On leaving the "station," however, and getting on the granite beyond, it was all right again.

Fig. 10.—*Section of the Valley of the Kahmil near Roodi.*




*a.* Alluvium. *b, b.* Limestone.

The ravines that run from this range to the south-west open out into the Jhelum River at Gingle, Oorie, and Kuttai; and the discovery that the crest or axes of this part of the North Pingal Range was of granite, accounted at once for the presence of enormous boulders of that rock which are to be seen at those three places, without the supposition that they had been "floated" by ice or "forced" by glaciers from the mountain of Hara-mook far to the East (see above, p. 221). Hara-mook is not granitic; nor does granite occur *in situ* for a considerable distance to the north-east.

The ravines from the North Pingal to the south-west are strewed with granite-boulders along their whole courses. The gorge of Baramula, along which the Jhelum escapes from the Kashmere valley, is, I see, considered to be due to some convulsion which broke through the Pingal Range; the correspondence between the opposite sides is supposed to show this. It is perfectly clear, however, that the great accumulation of boulders, angular rocks, and detritus to be found there has been brought down from the slopes and ravines on either side.

*Sir-nugger, Sept.* 3.—I went from Sir-nugger by boat to Dolamabad. Nothing much worth noticing on the way; the river flowing between high banks of alluvium, which shut out everything. The next day, 18th (the day of the Eclipse), I visited the ruins at Avāntipūr—a most curious place—the site of the old capital of Kashmere. In the old time the city was on the edge of a lake which must have occupied a large space in the valley, as below the city, where the river has now cut the ground away and exposed sections, may be seen thick layers of sand with broken pottery and bones, &c. This must have been near the place where, at that time, the women brought down their ghārōhs (water-pots), morning and evening, to fill, and when, as is the case now, great numbers are broken. The great thickness and numbers of these beds show that the lake must have changed its level by degrees, in periods of some duration.

Another curious feature of this place is—that, close by, a large temple (often noticed) has been literally buried in the alluvium, the top of the central portion being alone visible above the surface of the ground. Other portions were brought into view, about five years ago, by Major Cunningham. A few weeks' labour would clear the whole, which would then be one of the finest and most interesting ruins in the East; for Martund, to which I afterwards went, though of the same form and size, has been so destroyed by the bigoted Mussulmans, that hardly any of the beautiful stone-cutting now remains, but bits here and there, to show what once was.

On going up towards the Meerbal Pass into Kishtwar I found the first fossil shell* I have yet met with in all my wanderings here; it occurred in the limestone-rock at an elevation of 9000 feet. It is a Brachiopod, as you will see by the sketch.

*Oct.* 25.—All my letters of late have begun in some out-of-the-way spot, like the one I am now at (Pipran Station) up among the snows.

The ground I am now on is a high ridge, 12,000 to 13,000 feet in places, descending to 11,000 feet, running from the Pir Pingal Range, near the Mudul Pass, towards Kishtwar city. The axis is of granite and gneiss, forming the ridge; the lower slopes being of slate.

These crystalline rocks encircle the greater part of the valley of Kashmere, running from this on the north-east towards the Didsut

* This specimen having been received, and submitted to Mr. Davidson for examination, he has kindly supplied the following note:—

"Having compared this specimen of *Productus* with all the figures of the genus known to me, I have not been able to identify the species with any degree of certainty, and consider it perhaps new. The external sculpture has a somewhat irregular and peculiar quincunxial aspect not common to the *Productidæ*." —T. D.

country. I find it noticed in the south-west Pingal, aud now observe it in the north Pingal.

*Concluding Observations.*—There are one or two curious matters I would notice: most so are the water-worn beds of blocks and shingle which occur along both the Jhelum and the Chandra Bagha; and always at the junctions of large streams. These beds are often 200 and 300 feet in thickness. The question is, how were these formed? whether by glaciers having come down, or by masses of materials from the hills on either side having dammed the rivers. This last hypothesis is open to many objections. Glaciers would do it; but then one has to suppose a different climate to the present, namely, much colder, with a lower snow-line.

In an early condition of this region, and when upheaved by those convulsions which have produced it, the drainage-lines were evidently less perfect and connected than they now are; so that it presented numerous lakes, into which the torrents carried down their shingle and detritus. At the melting of the snows, in spring, the overflow from these lakes would be very great, and thus would work out courses for their waters. These rivers, even now, are wearing away their beds, as is evident wherever these lacustrine deposits are cut through (sometimes upwards of 200 feet thick), and seen resting on the fundamental rock.

In nearly every instance the beds of these rivers have been lowered into the rock which supports the alluvial accumulation, until by degrees the courses of the present rivers have been worked out.

As the drainage becomes more perfect, the stream and rivers would become narrower until they assumed the present size. The great Kashmere valley only differed from the others in extent—forming a small inland sea, into which the torrents from the Pingals carried down their shingle and boulders; whilst, at the melting of the snows, enormous quantities of angular blocks and of earthy detritus would slip down from the higher slopes, as happens now. This was the origin of the clay-deposits all over the valley (the Karéwah formation). The lacustrine or alluvial deposits of the central parts of the valley are of fine sediment; against the sides they contain a large admixture of angular rocks; and these always correspond with those of the high ranges above. The great Kashmere lake was drained by the sinking or erosion of the river-bed at Baramula; so that now the small lake near the city, and the larger Wuller, alone remain, the poor representatives of what once was. Anything which might obstruct the course of the Jhelum from Baramula at any of the narrow gorges, such as the falling in of masses of rock from above, would check the drainage at Baramula, and so raise the level of the water within the valley. This theory of mine to account for the appearances at Avāntipūr gets rid of the necessity of calling in recent depressions and elevations, which some writers have supposed necessary; but my theory, no doubt, has its objections; I should like to know them, that I may look more into this question.

In the geological sketch-map which I send, you will see, indicated by colours, granite, gneiss, two kinds of slate-rock, the limestone which contains the fossil mentioned above (p. 227), and sandstone. I have also marked the alluvial deposits at the junction of all the larger streams with the Chandra-Bagha, which I have before alluded to, taking as my theory, that the original structure of the country produced a series of small lakes at different levels, until in process of time the valleys were eroded down into a continuous line or slope of drainage.

The alluvial deposit of the plain of Kishtwar rests on limestone, into which the river has cut down. The alluvium does not stretch the whole way across the valley, but has been cut through on one side, and the plain slopes gradually up to the hills on the west of the town.

Fig. 11.—*Outline-sketch of the hills above Kishtwar; and Section of the Alluvium on the bank of the Chandra-Bagha.*


1. Menzil. 2. Phuhàrum. 3. Phuzaushurur. 4. Sarwal. 5. Brahmah. 6. Surputtu. 7. Rondu. 8. Kishtwar.

At a place called Serai, where I have marked in a bit of alluvium, it consisted of a mass of debris of all sorts, and I fancy must be the rubbish of an old glacier which descended from Pipran. Great streams of water must at some time have come down the valleys of this region; for all that run from Pipran and Dach to this junction with the Kasher Kohl are strewed with granite-boulders.

Iron is found in abundance at Dedreen and Seich, and made into cannon-knees. It is smelted in small furnaces, with bellows of goat-skin, worked by hand.

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## *On some* New Species *of* Eurypterus; *with Notes on the* Distribution *of the* Species. By J. W. Salter, Esq., F.G.S., of the Geological Survey of Great Britain.

[Read June 23, 1858.]

[Plate X.]

The genus *Eurypterus* of De Kay, though long known in America* and on the Continent, has attracted but little notice in this country since the time that Dr. Hibbert published his outline-sketches of

* Annals Lyc. Nat. Hist. New York, vol. i. pls. 14, 29, 1826.

this strange crustacean, in the 'Transactions of the Royal Society of Edinburgh' for 1836 (vol. xiii. pl. 12). His species, by far the largest in the genus, and probably not less than 3 feet long, had been previously noticed, under the name of *Idotea*, by Dr. Scouler, in the 'Edinburgh Journal of Natural Sciences' for 1831. Dr. Harlan too, in his 'Medical Researches,' had given similar, but rather more perfect figures of two species from Williamsville, Buffalo, in the State of New York. All these representations showed that the *Eurypterus* possessed at least three pairs of appendages, of which the hinder pair were dilated for swimming. More lately Dr. Ferd. Roemer gave a beautiful lithograph of the principal species in Meyer's 'Palæontographica' (vol. i. pl. 27); and Eichwald has since published in the 'Bulletin of the Imp. Soc. Nat. Moscow' for 1854 a complete series of illustrations of the Baltic species, *E. tetragonophthalmus*, Fischer, but under the name of *E. remipes*. The number and character of the appendages are the same in this as in the species previously published by Dr. Harlan.

Now that the structure of *Pterygotus** is fully understood, and the position of the eyes found to be lateral, and not on the surface of the carapace, it is easy to distinguish that genus from *Eurypterus* by superficial characters. There is, however, a further and very important difference in the small size of the antennæ in the latter genus: these are much shorter and slenderer than the swimming-feet, and not larger than the palpi. These palpi are five- or six-jointed, and furnished with only a minute smooth chela at the tip; while in *Pterygotus* the chelæ are very large and armed with long cutting teeth.

A new and very remarkable form of *Eurypterus* has been lately discovered in the middle beds of the Old Red Sandstone of Brecknockshire. Only the carapace has been yet found; but it is so strongly marked and characteristic that there can be no difficulty in identifying it. I propose to call it *Eurypterus Symondsii*, after the accomplished geologist who brought it under notice, and who has kindly presented casts to the Museum of the Geological Survey. The original is, I believe, in the choice collection of the Malvern Natural History Club, Malvern.

### EURYPTERUS SYMONDSII, spec. nov. Plate X. fig. 1.

The specimen†, of which we have only the exterior cast of the head, perfectly representing the surface, however, is impressed on a slab of brownish-grey micaceous grit, from the Upper Cornstones of Rowl-

* *Himantopterus* (Salter, Quart. Journ. Geol. Soc. vol. xiii. p. 27) proves to be the same genus as *Pterygotus*, though probably a good subgeneric form; but, as the name has been preoccupied for a genus of insects, *Erettopterus* is proposed in its place. The eyes are lateral in both subgenera; but they are long-oval on a rounded carapace in *Erettopterus*, and circular on a subquadrate carapace in *Pterygotus* proper. There are some other differences too, of subgeneric value, in the form of the epistoma and labrum; these will be more particularly described in Monograph I., Memoirs of the Geological Survey.

† See a notice of this specimen by the Rev. W. Symonds, in the Edin. New Phil. Journ. new series, vol. vi. pp. 257, 313.

stone, Brecknockshire, and was obtained by the Rev. Mr. Wenman. It is $2\frac{4}{10}$ inches long, and $2\frac{6}{10}$ inches broad at the wide anterior part, the greatest breadth being at the anterior third; the hinder edge is only 2 inches wide. The front margin is arched, somewhat truncate in front, and gibbous at the sides; and from about halfway up the head it is double, or has an inner raised ridge 2 lines distant from the edge. This ridge is continuous all round with the somewhat elevated border of the sides, in such a way that the carapace appears complete without the addition of the anterior border.

Exclusive of this border, which is concave and somewhat bent downwards, the surface of the head is but very gently convex, and is covered, except along the posterior margin, by elevations and furrows which give it a very rugged and lobed aspect. A deep Y-shaped vertical furrow, forked upwards at an angle of 30°, divides the space between the eyes, and occupies the middle third of the head*; the space between the branches is very convex.

A shallower depression takes its origin above the eyes, and radiates outward to the front margin; a pair of shorter furrows run obliquely outward behind those organs; another deep oblique depression occurs further back, at half an inch from the hinder border, and outside it a strong triangular lobe is marked out, partly by this furrow, and partly by a submarginal one which occupies about one-third the length of the head. Between these strong lateral lobes, and on the same level, a central tubercle, flanked by two depressions, occurs immediately behind the deep Y-shaped furrow first noticed. Lastly, there is a short and shallow pair of furrows in the central front portion of the head.

The posterior border is quite plain for a breadth of half an inch, and free from ridges or furrows of any kind. The posterior angles are acute, but not at all produced; and the hinder edge is sinuous, and without the raised border which runs round all the rest of the margin. The eyes are large, rounded, and circumscribed by a sunken space; they are placed more than halfway up the head, and as wide apart as they are distant from the outer margin. As they are abraded in this unique specimen, their shape and convexity are not to be ascertained; they appear to have been large and rounded.

The great size of this species distinguishes it from any previously described, except the *E. Scouleri* before noticed, the head of which is 8 inches wide. Neither of the American species, nor the Russian one above noticed, has a lobed carapace.

Several other forms, which I shall here briefly describe, have from time to time been brought under notice, chiefly by my excellent friends Messrs. Lightbody, Cocking, and Marston, of Ludlow. They are from the uppermost Ludlow beds and the overlying basement-beds of the Old Red Sandstone of that locality.

There is also at least one more from the Upper beds of the Old

* In *E. Scouleri* there is a ridge, forked *downwards*, between the eyes.

Red Sandstone from Kiltorkan, Co. Kilkenny. The most perfect specimens of this are in the collection of Trinity College, Dublin, and are here figured. It may possibly be referable to the *E. Scouleri*, from its great size; and I do not feel justified, in the absence of good specimens, in giving it a separate name.

E. Scouleri? Plate X. figs. 2, 3.

Fig. 2 represents a portion of one of the body-rings, and fig. 3 probably the hinder edge of the carapace (as indicated by fig. 11, in which a similar ornament occurs).

The substance of the crust in these Irish specimens is thin, and has cracked in longitudinal lines (fig. 3 *a*), *i. e.* perpendicular to the margin of the segments. The under surface is curiously reticulato-squamose, except at the hinder margin, where the crust is raised into strong subcircular plicæ and elongated tubercles (fig. 3 *b*).

These remarkable elongated tubercles occur on the margin of the carapace of *E. Scouleri*, and are visible in a photograph (kindly sent to me by H. Mackeson, Esq., of Hythe) of the specimen in the Andersonian Museum, Glasgow. They also occur on the hinder margin of the body-segments. It is much to be desired that this great fossil should be again figured, and with scientific detail.

*Locality.*—Kiltorkan Hill, Co. Kilkenny, Ireland. In the upper Old Red Sandstone.

E. pygmæus, Salter. Plate X. figs. 4–8.

(Quart. Journ. Geol. Soc. vol. xii. p. 99, plate 2. fig. 4.)

In the communication here referred to, the small half-oval carapace, with somewhat remote eyes, was figured, as well as a few front body-segments. I am now enabled to present the entire body and the caudal joint (figs. 5 and 6), with the sculpture of the head and body-rings (figs. 7 and 8), and to indicate the shape of the small broad swimming-foot, from a specimen in Mr. R. Banks's cabinet.

The body tapers rapidly backwards; it is not four times the length of the head, and is broadest at about the fourth segment. The first segment is very narrow, not above half the width of the second; and the rest are all transversely broad until the eighth, when they begin to lengthen out, the penultimate (eleventh) being square. The twelfth (telson) is regularly long-triangular, the length being scarcely more than twice the breadth. It is slightly keeled above; the sides are straight; the apex is not produced.

The elongation of the last body-joints before the tail helps to distinguish this small species from a closely-allied form in the shales of Lesmahago, Lanarkshire. This has the tail of the same shape, but a shorter head; and the penultimate body-joints are nearly one-and-a-half times as wide as long. In other respects it is very similar. It is described below as *E. chartarius*.

Of the swimming-foot we have the two expanded terminal joints;

taken together, they are as long as the head, and form an oblong oval, the deep notch in the penultimate joint being filled exactly by the oval terminal palette. The lobes on either side of this notch are very unequal, the posterior being much the larger and longer.

*Locality.*—Downton Sandstone (Uppermost Ludlow Rock) of Kington, Mr. R. Banks's Collection, fig. 7. Upper Ludlow Shales, Ludford Lane, Ludlow, figs. 7 & 8. Beds of passage at the base of the Old Red Sandstone, in the Railway-cutting, Ludlow (Messrs. Lightbody and Marston's cabinets), figs. 5 & 6.

E. MEGALOPS, spec. nov. Plate X. figs. 9–14.

Seven or eight inches long; the body-joints attenuated, and the tail acuminated; head semicircular, rough; eyes enormous, remote.

The head, in the largest specimens known, is $1\frac{1}{4}$ inch wide (and this would give fully the length here assigned to the body); it is wider than long, semicircular, granuloso-plicate, and with the hinder margin tuberculate.

The great reniform eyes are nearly one-third as long as the head, and (including the swollen base on which they are set, and the large circular eye-lobe which covers them) fully one-third, measured from within the eye-lobes; they are about their own diameter apart, and placed much more than halfway, but not quite two-thirds, up the head. The anterior margin of the head (carapace) is rounded, or very slightly angular, and margined all round the front.

This being a large and plentiful species in the Ludlow passage-beds, we are justified in associating with it the large and equally abundant body-rings which occur there,—the smaller ones being referable to the *E. pygmæus*. One specimen (fig. 13) shows the last six joints, and traces of others, with the terminal joint, *m*.

The seventh and eighth segments, *g*, *h*, are transversely broad, the eighth being nearly twice as wide as long; the ninth is three-quarters as long as wide; the penultimate is a little longer than wide, but nearly square. All have their posterior angles quadrate, except the seventh, in which they are a little produced.

The tail-joint, *m*, is narrowly ovate at the base, its broadest part being distant from the base of insertion by more than half the breadth, and thence gradually attenuated. The length is three-and-a-half-times the breadth. A strong median keel runs all down, and the edge is crenato-serrate; that of the body-segments appears to be quite smooth.

*Locality.*—Base of Old Red Sandstone, Ludlow Railway.

E. ACUMINATUS, spec. nov. Plate X. fig. 17, and probably fig. 19.

We have the tail-joints only. They are much broader at the base than in the last-described species; but possibly they belong to the opposite sex, as the individuals are nearly of the same size, and occur in the same strata, namely the passage-shales between the Upper Ludlow Rock and the Old Red Sandstone, in the Ludlow railway-cutting.

Telson expanded and cordate at base, the broadest portion being less distant from the insertion than one-third the entire breadth. From thence the tail-joint is regularly acuminated, the length being only two and a half times the breadth. The edge is crenato-serrate like the last. We have only the flat under surface.

*Locality.*—With *E. megalops* at Ludlow.

E. LINEARIS, spec. nov. Plate X. figs. 15, 16.

As this occurs generally in a lower stratum (Upper Ludlow Rock) than the last, it is little likely to have any relation to that species, though the differences are such as might be due to sex. If, however, *E. megalops* and *E. acuminatus* be one species, *E. linearis* must rank as distinct. The telson, the only part preserved, is greatly more elongated than in the other forms.

Telson linear, lanceolate, nearly five times as long as wide; the base very little expanded; broadest near the point of insertion, or rather parallel-sided for a short distance, and then attenuated. A strong median carina runs the whole length, elevated into a steep ridge near the origin of the joint; and the edge is so faintly crenate as to appear smooth to the naked eye.

Fig. 15 shows a broader telson, from the same bed, and it most probably bears the same relation to *E. linearis* that the last-described species does to *E. megalops*. From analogy we must suppose the broader tail-joint to belong to the female, and the narrower one to the male.

*Locality.*—The Upper Ludlow Rock of Ludlow, and the Downton Sandstone of Kington, Herefordshire.

E. ABBREVIATUS, spec. nov. Plate X. fig. 18.

A thoroughly distinct species, yet with very similar characters to those of *E. acuminatus*, as if the telson of that species had been greatly abbreviated.

Telson broadly trigonal at base,—forming a nearly equilateral triangle, of which the smooth thickened base forms one angle; the sides expand with a curved outline for about half the length of the joint, then suddenly contract and form a narrow, acuminate, serrated point.

We have only the under surface; the upper was probably keeled; the lower shows a faint longitudinal elevation proceeding from the thick base to the point. The serræ on the edge are very prominent. Length $\frac{7}{10}$ inch, width $\frac{5}{10}$ inch.

*Locality.*—Downton Sandstone of Kington, Herefordshire.

E. CHARTARIUS*, spec. nov.

I subjoin a diagnosis of this small form, mentioned above, and which will hereafter be figured in one of the Decades of the Geological Survey.

* Aquila chartacea, a Roman boy's kite, which the fossil much resembles.

*E. chartarius*, lanceolatus, postice attenuatus, $1\frac{1}{4}$ unciam longus, capite obtuso hemisphærico, quam corpore latiore; thoracis articulis latis brevibus, abdominis (etiam penultimo) transversis; caudâ brevi triangulatâ, acutâ atque non acuminatâ.

The eyes are small; the swimming-foot also small; its two dilated terminal joints, taken together, form an oblong palette, scarcely so long as the head.

*Locality.*—Lesmahago, Lanarkshire; in Upper Ludlow Rock (Mus. Pract. Geol.).

Eurypterus ?; pincers (antennæ). Pl. X. fig. 20.

It is thought worth while to figure here the chelate extremity of either *Pterygotus* or *Eurypterus*; most probably the latter, since all the species of *Pterygotus* of which we know the antennæ have longer chelæ, well supplied with teeth; these are, however, short and unarmed; and the fixed branch curves inwards, while the free joint is a little recurved to follow it, after the manner of the pincers in many recent *Crustacea*. The base is broad, short, and rhomboidal. If it belong to *Eurypterus* (the antennæ of which are known to have short small chelæ), it would probably be referable to the common *E. pygmæus*, which occurs in the same beds. A very similar, but much larger form is found in the Lower Ludlow Rock of Leintwardine.

*Locality.*—Bone-bed (Upper Ludlow), of Ludford. Mr. Lightbody's cabinet.

The distribution of the species of Eurypterus, so far as yet known, is as follows:—

1. Eurypterus ? sp. Lower Ludlow Rock, Leintwardine. This is doubtful.
2. E. Cephalaspis, *Salter*. Appendix, Brit. Palæoz. Foss. Woodwardian Museum, Cambridge. Pl. I E. fig. 21. Upper Ludlow Rock, Westmoreland.
3. E. pygmæus, *Salter*. Upper Ludlow, Downton Sandstone, and Base of Old Red Sandstone. Ludlow, and Kington, Herefordshire.
4. E. linearis, *Salter*. Upper Ludlow and Downton Sandstone, Ludlow.
5. E. acuminatus, *Salter*. Passage-beds, base of Old Red. Ludlow.
6. E. megalops, *Salter*. Passage-beds, Ludlow.
7. E. abbreviatus, *Salter*. Downton Rock, Kington, Herefordshire.
8. E. chartarius, *Salter*. Uppermost Ludlow, Lesmahago, Lanarkshire.
9. E. tetragonophthalmus, *Fischer*. Uppermost Silurian beds. Island of Œsel, Baltic; also in Podolia.
10. E. remipes, *De Kay*. Uppermost Silurian beds. Williamsville, Erie, Buffalo, U.S.
11. E. lacustris, *Harlan*. (Physical Researches, p. 297, plate not numbered, fig. 2.) Same locality as that of *E. remipes*? A distinct species from the last.
12. E. Symondsii, *Salter*. Old Red Sandstone, Brecon.
13. E. Scouleri ?, *Hibbert*. Upper Old Red Sandstone, Kiltorkan, Kilkenny Co. (If this should prove to be a new species, it might be named *E. Forbesii*; for Prof. E. Forbes first recorded its fragments from the freshwater beds of Kilkenny, where it is associated with *Sphenopteris*, *Lepidodendron*, *Anodon*, *Coccosteus*, and *Dendrodus*.)
14. E. Scouleri, *Hibbert*. Lower Carboniferous. Fifeshire.

The range of the genus, therefore, so far as yet known, certainly is confined between the Ludlow Rocks and the base of the Carboniferous system. Apparently, it did not commence to exist so soon as its gigantic ally, the *Pterygotus*; but it continued to live on longer, and attained its maximum of size in beds higher than those in which *Pterygotus* is known to have been found.

## EXPLANATION OF PLATE X.

Fig. 1. Eurypterus Symondsii, *Salter*. Head. Upper beds of the Cornstones, Old Red Sandstone, Rowlestone, Brecknockshire.

„ 2. E. Scouleri? *Hibbert*. Fragment of a body-ring.
„ 3 *a*, 3 *b*. —— Edge of the carapace.
} Upper beds of Old Red Sandstone, Kiltorkan, Kilkenny.

„ 4. E. pygmæus, *Salter*. Head, body-joints, and swimming-foot. Downton Sandstone, Kington. Mr. R. Banks's collection.

„ 5. —— Head, body-joints, and tail.
„ 6. —— Tail.
} Basement-beds of the Old Red Sandstone, Ludlow Railway.

„ 7. —— Part of the head, magnified, showing ornament.
„ 8. —— Part of first body-joint, magnified.
} Upper Ludlow Rock, Ludford.

„ 9. E. megalops, *Salter*. Head, magnified.
„ 10. —— Head, natural size.
} Base of the Old Red Sandstone, Ludlow Railway.

(Figs. 5–10: Mr. Lightbody's collection.)

„ 11. —— The eye and a portion of the margin of the head. Base of the Old Red Sandstone, Ludlow Railway. Mus. Pract. Geology.

„ 12. —— Part of the head, magnified, showing the granular surface.
„ 13. —— Body-joints and tail.
} Base of the Old Red Sandstone, Ludlow Railway. Mr. R. Lightbody's collection.

„ 14. —— Tail. Base of the Old Red Sandstone, Ludlow Railway. Mus. Pract. Geology.

„ 15. E. linearis, *Salter*. Tail-joint. Upper Ludlow-rock, Ludford; Kington. Mus. Pract. Geology.

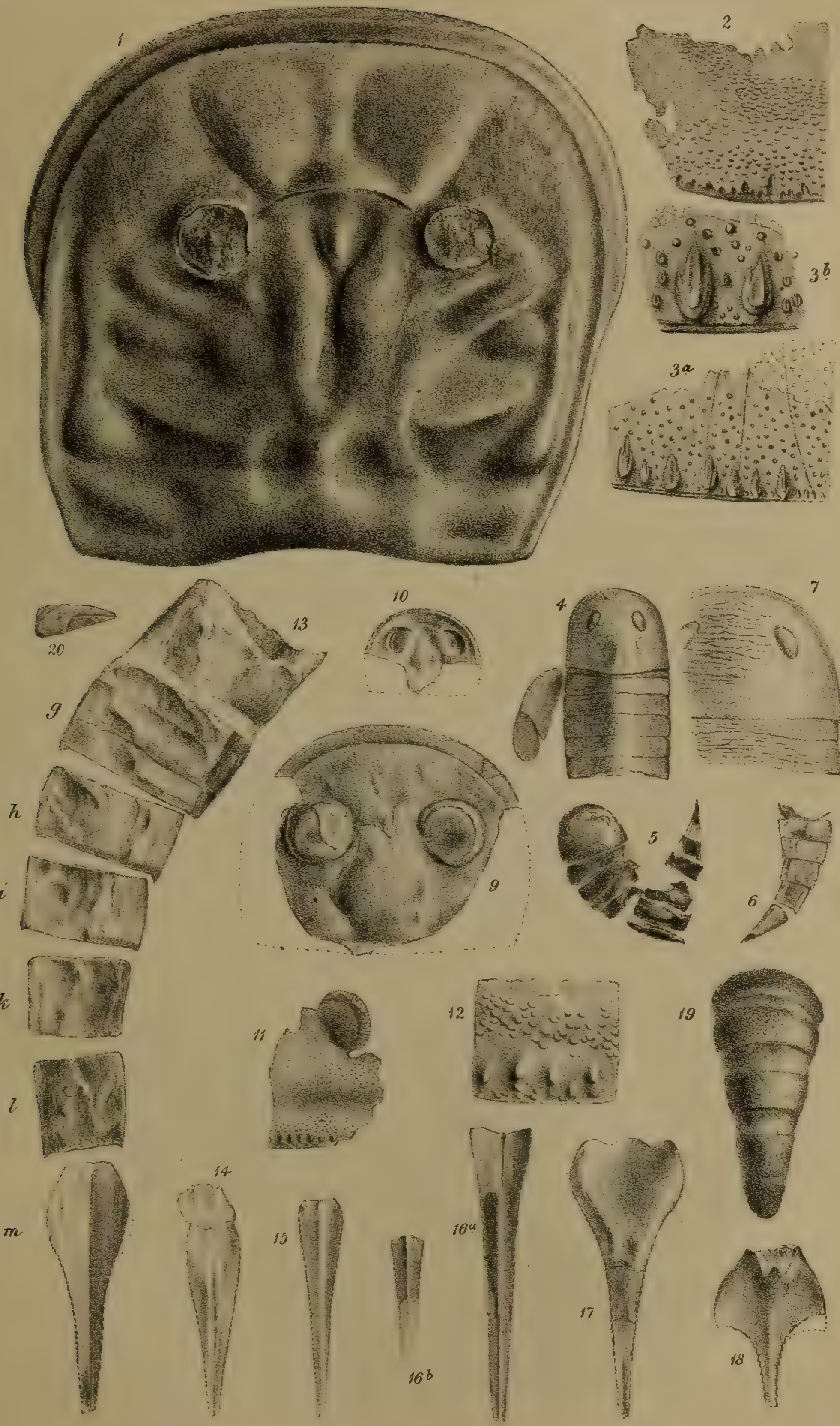
„ 16 *a*, 16 *b*.—Tail. Downton Sandstone, Kington. Mr. R. Banks's collection.

„ 17. E. acuminatus, *Salter*. Tail. Passage-beds at the base of the Old Red Sandstone, Ludlow Railway. Mr. Lightbody's collection.

„ 18. E. abbreviatus, *Salter*. Tail. Downton Sandstone, Kington. Mr. R. Banks's collection.

„ 19. E. acuminatus? Body-joints and tail.

„ 20. Eurypterus? Chelate termination of antenna? Bone-bed, Ludlow. Mr. Lightbody's collection.




G. West lith. ad nat.

W. West imp.

EURYPTERUS.

## *Description of a* New Fossil Crustacean *from the* Lower Greensand.

By Charles Gould, Esq., B.A., of the Geological Survey of Great Britain.

[Communicated by Prof. Huxley, F.R.S., F.G.S.]

(Read June 23, 1858.)

I regard the Crustacean which I am about to describe with peculiar interest, on account of its belonging to that group of the *Brachyura* which comprehends the highest forms of the class, and of which hitherto but one species (*Mithracia libinoides*, Bell*) has been described as occurring in the fossil state in Great Britain.

At present I am only aware of the existence of two specimens of the species which I shall here describe,—one in the collection at the British Museum, the other in that of the Geological Survey of Great Britain; both are from the Lower Greensand of Atherfield in the Isle of Wight, and in each the carapace only is preserved. It is from an examination of these specimens that I have taken the following characters.

Figs. 1, 2, 3.—*Mithracites Vectensis,* natural size.

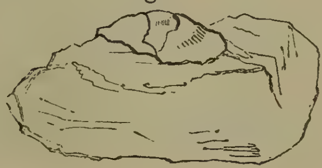
Fig. 1.

Carapace, viewed from above.

Fig. 2.

Front view of the Carapace.

Fig. 3.



Side view of the Carapace, in outline.

Mithracites Vectensis, nov. gen. et spec.

*Carapace*: arched in front, somewhat depressed behind, rotundate; length slightly exceeding the breadth, which is greatest at the

* Monograph Fossil Malacostr. Crust. Great Britain, Part I. Crustacea of the London Clay. (Palæontograph. Soc.) 1858, p. 9, pl. 5. figs. 10–12.

level of the anterior cardiac region. Front produced into a lamellar rostrum, of equal length and breadth, grooved in the middle, and terminating anteriorly in a point without any bifurcation. In both the specimens examined the remainder of the fronto-orbital portion of the carapace is imperfect, and partially concealed in the matrix; but the ocular peduncle was apparently inserted just beneath the rostrum, and the eyes folded back into a slightly concave orbit, the upper edge of which is less advanced than the former.

Cephalic and meso-branchial grooves deep and distinct; gastro-hepatic less so; meta-branchial furrow indistinguishable.

In the smaller specimen the meta-gastric and uro-gastric regions are separated from each other by a transverse furrow, and a separation of the lobes in each of these regions is indicated by a longitudinal median furrow. In the larger specimen these parts are imperfect; but the grooves, as far as they can be seen, appear to be less distinct. In both specimens the anterior cardiac region is distinguishable. The meso-gastric region is triangular in form, with the apex extending forwards between the lobes of the epi- and proto-gastric regions. The hepatic region is small, and has an obtuse spine at its point of contact with the orbits. The upper surface of the carapace is covered with two species of tubercles, the smaller of which are irregularly scattered over it, and the latter more definitely arranged. Two, of a fusiform shape, are situated at the base of the rostrum, one on either side of the median groove, and are followed by five others disposed nearly in a straight line across the carapace. The central one of these is situated in the apex of the triangular meso-gastric region, and is succeeded at a short interval by another and somewhat larger tubercle. The branchial regions on either side also carry five or six tubercles.

*Affinities.*—Although the general characters of the carapace (such as its peculiar form, comparative dimensions, the production of its front into an elongated rostrum, &c.) sufficiently indicate the position which this species occupies among the *Brachyura*, still its affinities with existing genera are not sufficiently close to allow of its being placed among the members of either of them, and I therefore propose to give it the generic title of *Mithracites*. Fully recognizing the difficulty of obtaining complete generic characters from imperfect specimens of a single species, I have only ventured to give the few following from the scanty material at my command, leaving them to be added to, or modified, if necessary, after the examination of any more perfect examples which may be subsequently obtained.

## Genus Mithracites.

*Carapace* slightly longer than broad, and having most of the regions well defined; front produced into a rostrum, not bilobed; orbits shallow, with the under edge anterior to the upper.

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# POSTPONED PAPERS.

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## *On the* Palæozoic Basin *of the* State *of* New York.

Part III. *An Inquiry into the Sedimentary and other External Relations of the Palæozoic Fossils of the State of New York**. By J. J. Bigsby, M.D., V.P.G.S., formerly British Secretary to the Canadian Boundary Commission.

[Read May 26, 1858.]

CONTENTS.



*Introduction.*—The objects proposed in this inquiry are—to give more precision to facts as yet imperfectly ascertained, and to discover, if possible, new materials for the history of these early times, and new points of connexion between the palæozoic basins of the State of New York and of Wales—countries which are therefore the subject of frequent comparison in these pages.

This communication is divided into four parts. The first part, after a few preliminary observations on the agencies by which the sediments or sea-bottoms were laid down, will treat of their mineral character. The second will be devoted to the distribution and immediate relations of animal life to the strata which the fossil remains occupy. The third will deal with the "recurrence" or vertical range of these fossil species,—their order of precedence, duration, increment, and decrement throughout the older palæozoic epochs. The fourth, and concluding, part will consist of general statements and inferences.

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* For Parts I. and II. see Quart. Journ. Geol. Soc. vol. xiv. p. 335 and p. 427.

By the expression "external relations" is meant such as do not directly lead us to the consideration of structural or physiological distinctions; the latter belong to a separate and very important field of investigation.

§ 1. *Conditions and characters of Sediments.*—It being a generally received fact that palæozoic fossils usually passed their lives in and about the sedimentary strata in which they are found, some very brief remarks on the origin and nature of the latter may be excused. The agents concerned in the formation of strata may be divided into two great classes:—1st. The constant and superficial, often called "Neptunian." 2ndly. The modifying, or occasional and subterranean, often called "Plutonic."

The first, *or constant*, causes are mechanical and chemical, both being in universal and ceaseless action. The *mechanical* agencies operate, on land, by comminution and degradation, and in the ocean, by removing and redepositing suspended matters by the means of currents, pelagic, estuarine, and fluviatile—all liable to variations, stoppage, and reversion. Their greatest activity is experienced, as is well known, near the land, where broken up and removable substances are most plentiful. The nature of the sea-bottom is therefore usually determined by the geological constitution of the neighbouring land and its coasts, the very outline of the latter having a powerful influence, as they are high or low, straight or curved. Of the details of these currents in the palæozoic times, their force, direction, &c., we know but little as yet; for they were not those of the present day—the position, form, and quantity of the dry land being different. Many appearances exist, however, tending to prove that during the deposition of the middle stage of the Silurian system of New York a broad current set in from the region now sunk under the Atlantic, in a W.N.W. direction, and overspread that State and the countries still more westerly with various forms of detritus, which at first (on the eastern edge of middle North America) was a conglomerate, and then a grit, and successively a deposit arenaceous, argillaceous, and calcareous, as it progressed into the deep western seas of the epoch. Precisely similar phenomena occur in Bohemia, except that the currents and their contents come from opposite quarters, N.E. and S.W., at different stages of the Silurian era*.

The *chemical causes* are everywhere in action, dissolving and converting, simultaneously with the mechanical. In the high seas they are often alone. There is reason to believe that the mineral ingredients of sea-water are always undergoing minute changes of composition, which result in precipitations,—by far the most part of this being effected by the animals inhabiting it, and principally by the Rhizopods, assisted by the minute Diatomaceous vegetables.

The second class of causes, *the occasional and modifying*, employed in the deposition or the derangement of strata, consist of insensible oscillations of level, crust-ruptures, or elevations. The slow depressions and upheavals of the earth's surface, which have been

* Barrande, 'Système Silurienne Bohème,' p. 62.

called secular oscillations, have produced, we must remember, vast changes in the nature of the sediments by withdrawing the sea-bottoms from certain influences and exposing them to others. They are often repeated on the same spot, and create new features in land and sea,—new islands, continents, straits, and broad oceans. Shutting up old communications, they may open new ones, and introduce currents laden with other faunæ and floræ. Hence, it is evident, arise a multitude of zoological complications: migration begins in one place, is stopped at another; a community of living beings perishes, to be replaced by a new group. Similar observations may be made on sudden uplifts, sometimes endowed with tremendous and far-extending energy; leaving behind them, at the same time, more or less of metamorphism.

The characteristics of pelagic, estuarine, and fluviatile deposits, so important in palæozoic investigations, have been well explained by Edward Forbes and Constant Prévost, and must be familiar to my readers. We need not dwell on the effects which oceanic waters, their vegetation, and suspended matters exert upon the production and perfection of animal life. These effects result from the character of the mineral contents of the sea, its depth, distance from land, and its temperature. The saline ingredients of the sea must have always been nearly the same as at present, as well as the degree of dilution. The presence of iron, of free acids, and of many other foreign substances is commonly fatal to animal life. When the first of these abounds in fossiliferous strata, it has usually been introduced after the death of the resident animals. Depth of sea and distance from land are important considerations as regards life, as has been admirably shown in the zoological zones and parallels established by Edward Forbes.

In reference to temperature, we find that differences in latitude had not the same effect in palæozoic times that they have had since. Everything points to the prevalence of a uniform and rather high temperature during these primal times and long afterwards. Their palæozoic species are widely disseminated. An Australian or an Arctic species may be found in a Chinese, British, or American rock; and this not as an exceptional fact. Every small section of the thermometric scale, embracing perhaps only a few degrees of heat, has its own assemblage of life as regards the present seas. M. Deshayes points out that the number of species increases at the present day as we approach the equator,—there being only 10 or 12 in latitude 80°, and, by progressive increase, more than 900 in the seas of Guinea; such is the life-multiplying power of heat. We must always remember that marine life requires for its well-being a resting-place, security, food, and a proper medium for the performance of physiological acts.

§ 2. *Palœozoic Sediments; their nature.*—The complete development of the Silurian system in Wales and the border-counties*, its volcanic

* In the frequent references throughout these pages to the palæozoic area of Wales and the adjacent English counties, the single word "Wales" only will be employed.

disturbances and intercalations, and the ample elucidation it has received from geological observers of the highest class, have rendered it a most convenient and trustworthy standard of comparison with similar basins. In the early palæozoic times, we may here remark, and especially at the period of the Lingula-flags (or Potsdam Sandstone, their New York representative), a waste of shallow waters almost wholly overspread the earth. Here and there were lands, probably low, composed of the older metamorphic rocks, and forming the widely separated and devious coast-lines of immense sea-basins, wherein were deposited mineral sediments, chiefly through the medium of vital processes, but greatly also by currents,—the coarse near to, and the fine remote from, the dry land,—such action commencing from the moment any given region was immersed beneath the waters. These deposits constitute the sedimentary strata, the subject of the observations now about to be made. Those of New York may be usefully arranged under the following seventeen heads, namely:—

| | |
|---|---|
| Siliceous Conglomerate. | Calcareous Grit. |
| Siliceous Grit. | Calcareous Sandstone. |
| Siliceous Sandstone. | Argillo-calcareous Shale. |
| Argillaceous Sandstone. | Calcareo-argillaceous Shale. |
| Micaceo-argillaceous Sandstone. | Micaceo-argillaceous Shale. |
| Ferruginous Sandstone. | Siliceous Limestone. |
| Iron-ore. | Magnesio-argillaceous Limestone. |
| Calcareous Conglomerate. | Argillaceous Limestone. |

Pure Limestone.

These seventeen materials, varying in the proportions of their ingredients, constitute the whole sedimentary basin of New York. They are good types,—some one or more occupying each of the group-sections into which this basin has been divided. Magnesia enters largely into the composition of some of the sandstones and limestones of the western continuations of this basin (Wisconsin, &c.); but not, as far as I am aware, within the limits of New York, excepting in the Onondaga-Salt Rocks. The Clinton iron-ore of New York is of workable value; it is an oolitic lenticular clay-iron-ore (Vanuxem, p. 83).

The manner in which this distribution has taken place is seen at a glance in the Table of mineral characters of the palæozoic strata of this State (No. I.). This Table exhibits, first, in separate columns, the variations in composition undergone by each section, giving the predominant character of each in the last column.

The following inferences may be drawn from this Table: they seem to be of some importance. 1. The three great mineral forms, siliceous sand, clay, and lime, are nearly equal in quantity. The other minerals are rare and uninfluential, except iron and magnesia, which, however, are in less quantity than those first mentioned. 2. The great classes of rock, arenaceous, calcareous, and siliceous, are usually massed together; but not often in a state of purity. 3. The lithological grounds on which the State-geologists of New York have based their stratigraphical arrangements are well defined. 4.

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New Yor

Catskill Group
Chemung Rocks
Portage Rocks
Genesee Slate ...
Tully Limestone
Hamilton Rocks
Marcellus Shale
Corniferous Lim
Onondaga Limes
Schoharie Grit
Cauda-Galli Grit
Oriskany Sandst
Upper Pentamer
Delthyris Shaly
Lower Pentamer
Waterlime Limes
Onondaga-Salt R
Coralline Limest
Niagara Rocks
Clinton Rocks
Medina Sandston
Oneida Conglom
Hudson-River R
Utica Slate .......
Trenton Limesto
Birdseye Limesto
Chazy Limestone
Calciferous Sands
Potsdam Sandsto

—*The Palæozoic Sediments of Wales and the adjacent Counties*.*

| Sediments. | Localities. |
|---|---|
| erate, quartzose ............... | May Hill. |
| erate, calcareous............... | (Frequent.) |
| ite, quartzose ................. | Park Lane |
| caceous ........................ | Lechclawdd. |
| grey micaceous ................. | Horeb Chapel. |
| ck, green....................... | Lechclawdd. |
| yellow, micaceous .............. | Storm Hill. |
| e, grey, micaceous ............. | Lechclawdd. |
| e, fine, micaceous ............. | Maudinam. |
| e, fine ........................ | May Hill. |
| ................................ | Bala, Wenloch Sh. |
| sandy .......................... | |
| calcareous ..................... | |
| coarse (grit?).................. | Golden Grove. |
| green .......................... | Dinas Brau. |
| olive, arenaceous .............. | Keeper's Lodge, Llandovery. |
| dark ........................... | Builth, &c. |
| black .......................... | Cefu ddw. |
| ................................ | Ludlow. |
| eous shale ..................... | Pensarn. |
| ve.............................. | Caradoc. |
| ck ............................. | |
| e .............................. | Bala. |
| eenish. (Lingula-flags)...... | Penmorfa. |
| Rock, olive .................... | Mortimer's Cross. |
| Rock, green .................... | Park Lane. |
| pure? .......................... | Aymestry. |
| pure and argillaceous... | Dudley. |
| argillaceous.................... | Woolhope. |
| arenaceous ..................... | Bala. |

* From Murchison and M'Coy.

e IV.—*Analyses of some Rocks from Canada.*

| Minerals | Lower Silurian. | | | | Upper Silurian. | |
|---|---|---|---|---|---|---|
| | Trenton Limestone; La Cloche, Lake Huron. | Trenton Limestone; Lake Simcoe. | Trenton Limestone; Montmorenci Falls, Quebec. | Hudson-River Rocks; Quebec. | Niagara Limestone; Drummond Isle, Lake Huron. | Niagara Limestone; Isles North of Drummond Isle. |
| Carbonate of lime | 38·5 | 99 | 90 | 78 | 33 | 43·04 |
| Carbonate of Mag | 29·5 | | | | 42 | 34·10 |
| Carbonate of Man | 18 | ... | ... | ... | 6·25 | 1 |
| Alumina and Sesq | 10 | 1 | 10 | 15·5 | 7 | ... |
| Phosphoric acid.. | ... | ... | ... | ... | 8·4 | 14·80 |
| Insoluble ........ | ... | ... | ... | ... | 2·30 | 1·06 |
| Organic matter .. | ... | ... | ... | ... | 1 | 5 |
| Water............ | ... | ... | ... | 6·5 | ... | ... |
| Loss ............ | | | | | | |
| | 96 | 100 | 100 | 100 | 99·95 | 99 |

Table I.—*Showing the Sedimentary Constituents of the Groups of Strata in the New York Basin.*

| New York Sections. | Thickness. | Siliceous Conglomerate. | Siliceous Grit. | Siliceous Sandstone. | Argillaceous Shaly Sandstone. | Ferruginous Sandstone. | Iron-Ore. | Calcareous Conglomerate. | Calcareous Grit. | Calcareous Sandstone. | Argillaceous Shale. | Calcareous Shale. | Siliceous Limestone. | Magnesian Argillaceous Limestone. | Argillaceous Limestone. | Limestone. | Prevailing Mineral. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Catskill Group | 2000 | * | * | ... | * | * | ... | * | ... | ... | ... | ... | ... | ... | ... | ... | Clay and Silex. |
| Chemung Rocks | 1900 | * | ... | * | * | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | Clay and Silex. |
| Portage Rocks | 1000 | † | † | † | * | ... | ... | ... | ... | ... | * | ... | ... | ... | ... | ... | Clay and Silex. |
| Genesee Slate | 100 | ... | ... | ... | * | ... | ... | ... | ... | ... | * | * | ... | ... | ... | ... | Clay. |
| Tully Limestone | 15 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | ... | * | ... | Limestone. |
| Hamilton Rocks | 800 | ... | ... | ... | * | ... | ... | ... | ... | ... | ... | * | ... | ... | * | ... | Calcareous Shale. |
| Marcellus Shale | 100 | ... | ... | ... | * | ... | ... | ... | ... | ... | * | * | ... | ... | ... | ... | Black bituminous Slate. |
| Corniferous Limestone | 70 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | ... | ... | Limestone. |
| Onondaga Limestone | 25 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | Limestone. |
| Schoharie Grit | 10 | ... | ... | ... | ... | ... | ... | ... | * | * | ... | ... | ... | ... | ... | ... | Lime and Silex. |
| Cauda-Galli Grit | 40 | ... | ... | ... | * | ... | ... | ... | ... | * | ... | ... | ... | ... | ... | ... | Calcareous and Argillaceous Sandstone. |
| Oriskany Sandstone | 70 | ... | ... | * | ... | ... | ... | ... | * | * | ... | ... | ... | ... | ... | ... | Calcareous Sandstone. |
| Upper Pentamerus Limestone | 30 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | * | Limestone. |
| Delthyris Shaly Limestone | 40 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | Limestone. |
| Lower Pentamerus Limestone | 60 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | ... | Limestone. |
| Waterlime Limestone | 100 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | ... | Limestone. |
| Onondaga-Salt Rocks | 1000 | ... | ... | ... | * | ... | ... | ... | ... | ... | ... | ... | ... | * | * | ... | Silex and Clay. |
| Coralline Limestone of Schoharie | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | Limestone. |
| Niagara Rocks | 240 | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | * | * | * | ... | Limestone. |
| Clinton Rocks } | | * | * | * | * | * | * | ... | ... | * | * | * | ... | ... | * | ... | Silex. |
| Medina Sandstone } | 1200 | ... | * | * | * | * | ... | ... | ... | * | ... | ... | ... | ... | ... | ... | Argillaceous Sandstone. |
| Oneida Conglomerate } | | * | * | * | * | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | Quartz. |
| Hudson-River Rocks | 650 | * | * | * | * | ... | ... | * | ... | ... | * | ... | ... | ... | * | * | Quartz and Clay. |
| Utica Slate | 200 | ... | ... | ... | ... | ... | ... | ... | ... | * | * | ... | ... | ... | ... | ... | Argillaceous Shale. |
| Trenton Limestone | 350 | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | ... | ... | * | * | Argillaceous Limestone. |
| Birdseye Limestone | 30 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | * | Siliceous Pure Limestone. |
| Chazy Limestone | 100 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | Limestone. |
| Calciferous Sandstone } | 700 | ... | ... | ... | * | ... | ... | ... | ... | * | ... | ... | ... | ... | ... | ... | Calcareous Sandstone. |
| Potsdam Sandstone } | | * | ... | * | * | * | ... | ... | ... | * | ... | ... | ... | ... | ... | ... | Siliceous Sandstone. |

† Micaceous Shale.

Table II.—*The Palæozoic Sediments of Wales and the adjacent Counties*.*

| Sediments. | Localities. |
|---|---|
| Conglomerate, quartzose | May Hill. |
| Conglomerate, calcareous | (Frequent.) |
| Grits, white, quartzose | Park Lane |
| Grits, micaceous | Lechclawdd. |
| Quarzite, grey micaceous | Horeb Chapel. |
| Quartz-rock, green | Lechclawdd. |
| Tilestone, yellow, micaceous | Storm Hill. |
| Sandstone, grey, micaceous | Lechclawdd. |
| Sandstone, fine, micaceous | Maudinam. |
| Sandstone, fine | May Hill. |
| Flagstone | |
| Schists { sandy | } Bala, Wenloch Sh. |
| Schists { calcareous | } |
| Schists { coarse (grit ?) | Golden Grove. |
| Schists { green | Dinas Brau. |
| Schists { olive, arenaceous | Keeper's Lodge, Llandovery. |
| Schists { dark | Builth, &c. |
| Schists { black | Cefu ddw. |
| Mudstone | Ludlow. |
| Carbonaceous shale | Pensarn. |
| Shale, olive | } Caradoc. |
| Shale, black | } |
| Slates, fine | Bala. |
| Slates, greenish. (Lingula-flags) | Penmorfa. |
| Ludlow Rock, olive | Mortimer's Cross. |
| Ludlow Rock, green | Park Lane. |
| Limestone { pure ? | Aymestry. |
| Limestone { pure and argillaceous | Dudley. |
| Limestone { argillaceous | Woolhope. |
| Limestone { arenaceous | Bala. |

* From Murchison and M'Coy.

Table III.—*Analyses of some European Palæozoic Strata.*

| Minerals. | Upper Silurian. Wenlock Limestone. Dudley. | Middle Silurian. Dolomite. Mayhill Section. | Lower Silurian. Bala Limestone. Yspatty Evan. | Lower Silurian. Bala Limestone. Rhiwlas. | Lower Silurian. Llandeilo Rock. Dinover Pk. near Llandeilo. | Cambrian. Cambrian Limestone. Church Stretton, Longmynd. | Cambrian. Limestone. Craigmuir, Inverary. | Cambrian. Veins and masses of White Limestone. Kragerod, Norway. |
|---|---|---|---|---|---|---|---|---|
| Carbonate of lime | 90·09 | 60·8 | 39·54 | 19·51 | 79·97 | 63·10 | 73·34 | 89·24 |
| Carbonate of Magnesia | 1·26 | 28·3 | 1·85 | 1·04 | ·52 | ·80 | ·28 | ·19 |
| Carbonate of Manganese | ... | 1·4 | ... | ... | ... | | ... | ·19 |
| Alumina and Sesq. ox. iron | 2·30 | Al. ·3 | 4·68 | ·82 | ·82 | 8·51 | 1·16 | ·07 |
| Phosphoric acid | ·46 | ... | ·16 | ·56 | ·56 | ·55 | ·44 | ·21 |
| Insoluble | 5·13 | 4 | 52·27 | 73·13 | 17·85 | 26·98 | 24·03 | 8·29 |
| Organic matter | ... | *6·7 | ·73 | 3·50 | ·56 | ·33 | ·21 | ·77 |
| Water | ·76 | ·8 | ·53 | } 1·47 | ... | ... | ·54 | ·22 |
| Loss | ... | | ·24 | } | ... | ... | ... | ·82 |
| | 100·000 | 100·000 | 100·000 | 100·000 | 100·000 | 100·000 | 100·000 | 100·000 |

* Protocarbonate of Iron.

Table IV.—*Analyses of some Rocks from Canada.*

| Minerals. | Lower Silurian. Trenton Limestone; La Cloche, Lake Huron. | Lower Silurian. Trenton Limestone; Lake Simcoe. | Lower Silurian. Trenton Limestone; Montmorenci Falls, Quebec. | Lower Silurian. Hudson-River Rocks; Quebec. | Upper Silurian. Niagara Limestone; Drummond Isle, Lake Huron. | Upper Silurian. Niagara Limestone: Isles North of Drummond Isle. |
|---|---|---|---|---|---|---|
| Lime | 38·5 } | 99 | 90 | 78 | { 33 | 43·04 |
| Carbonic Acid | 29·5 } | | | | { 42 | 34·10 |
| Silex | 18 | ... | ... | ... | 6·25 | 1 |
| Alumina | 10 | 1 | 10 | 15·5 | 7 | ... |
| Magnesia | ... | ... | ... | ... | 8·4 | 14·80 |
| Iron | ... | ... | ... | ... | 2·30 | 1·06 |
| Water | ... | ... | ... | ... | 1 | 5 |
| Coal & Bitumen | ... | ... | ... | 6·5 | ... | ... |
| | 96 | 100 | 100 | 100 | 99·95 | 99 |

Conglomerates and grits form the basement of the greater divisions, and mark the transitions (see Potsdam Sandstone, Oneida Conglomerate, Oriskany Sandstone, and Catskill Group). 5. The great similarity between Hudson-River Rocks and Oneida Conglomerate is thus well brought out, though in supposed different stages. Locally they are sometimes undistinguishable. 6. The middle or transitional Silurian stage, as well as the section immediately below, exhibits numerous and great mineral changes and complications, such as are indicative of frequent movement. The Hudson-River Rocks contain eight varieties of sediments; the Medina Sandstone contains five; Clinton Rocks, ten; besides the minuter alterations, which it would be profitless to describe. 7. Excepting in the Middle Silurian stage, lithological differences on the same horizon are moderate in extent, although many and sometimes occupying large spaces. 8. The arenaceous and argillaceous strata (usually near old coast-lines) are more changeable than the calcareous, the latter being formed under quieter conditions.

Our Synoptical View * pointed out, as a determinate law, that, with rare exceptions, these sediments graduate into each other, just as we see in Wales, in parts of America, Scandinavia, and Russia. Although this change takes place slowly and tranquilly, the majority of the organic beings belonging to the terminated section perish. We are thus taught that destruction of life can take place without the accompaniment of a marked disturbing force.

The sedimentary deposits of Wales and the adjacent English counties only agree to a certain extent with those of New York. When beyond the metamorphic action of the Appalachian crust-movement, the latter are little affected in their mineral condition by influences acting from below. The shales are soft and shivery, the sandstones of moderate hardness, and the limestones are dark-coloured, fine-granular, or crystalline (fossiliferous), and in abruptly separated beds. It is often remarked that fossiliferous beds of crystalline limestone are intercalated with others of opake granular structure, the separating planes being perfectly abrupt. The crystalline form cannot here have been derived from metamorphism, because, if so, it would have affected the strata beneath. The supposition of great purity in the crystalline rock will not help us, because it is well known that chemical precipitation throws down pure carbonate of lime in the opake amorphous form (Carpenter). The points of difference between the two kinds of beds are these: the amorphous beds are very dark-coloured, often fetid, and have few or no fossils; whereas the crystalline are pale-grey, are made up of crushed fossils, and present rhomboidal facets. The cleavages are often rare and obscure. This is not the condition of the sedimentary rocks of Wales. Metamorphic action has been in frequent play among its mountain-masses. We find here (as, under similar circumstances, in Bohemia, according to Barrande) an abundance of quartzites, micaceous sandstone, flagstones, roofing-slates, distorted shells, and much powdery chlorite. Thirty forms of sedimentary

* Quart. Journ. Geol. Soc. vol. xiv. p. 335.

rocks may be distinguished in Wales, most of them having exerted great influence over ancient life. Thus, there are five varieties of micaceous sandstone or grit, whilst there appears to be only one in New York: twelve forms of schist or shale are met with; but limestone undergoes only the mutations common in New York.

In constructing the Table of sedimentary positions of the Silurian fauna and flora of Wales (Table VI.), I have not arranged them under these thirty heads. By limiting them to eleven, it is hoped that every practical advantage is secured, and some disadvantages avoided. These Welsh strata differ from those of New York in the prevalence of micaceo-siliceous sandstone, in the absence of rich beds of iron-ore, and in the presence of the green colouring-matter of the mudstones. The sedimentary strata of the Welsh area have been analysed in a few instances only, by Messrs. Trenham Reeks, David Forbes, and Prof. Forchhammer. These analyses are annexed, one being added from Scotland and another from Norway. Those of New York have not been examined; but the late Dr. Troost, Professor of Geology at Nashville College, Tennessee, kindly submitted to chemical analysis, at my request, some Canadian rocks, a continuation of the basin of New York.

It is seen from Table IV., imperfect as it is, that the constituents of the Canadian strata are few and simple, and that they are in different proportions in the same stratum at different places. In the Table of Welsh Rocks (No. III.) much less silex is noticed in the Lower Silurian, while in the Wenlock limestone of Dudley there is often little alumina, so plentiful in the Niagara Limestone of central New York. It is possible that phosphoric acid, detected in the Welsh rocks by David Forbes, has not been met with in the earlier palæozoic strata of this State because it has not been looked for—and perhaps for want of the detective reagent we have of late years become possessed of. The phosphates are common among American coal-measures, and in extraordinary abundance in the older metamorphic rocks. The want of a greater number of exact analyses becomes of less importance on account of the frequent changes in mineral proportions observed in almost all North American sedimentary rocks. The Hudson-River and Clinton sections vary through almost all the possible mutations of sand, clay, lime, and iron. The Niagara Limestone at the west end of Lake Ontario is pure, siliceous, or argillaceous; while it is invariably magnesian about the west end of Lake Huron, 500 miles W.N.W., probably on account of the proximity of hypogene rocks. Calciferous sandstone, reported by Emmons to be free from magnesia in Jefferson County, New York, is, according to Foster, rich in that mineral on the south shore of Lake Superior.

As regards the Devonian system of New York, the changes in the calcareous rocks of its lower stage and in the shales of the middle stage are commonly far too numerous and too gradual to admit of useful quantitative analysis. These observations apply also to Wales*.

* The subject of mineral deposition is most ably treated in the writings of

§ 3. *On the distribution and immediate relations of Palæozoic Animal Life in Wales and the State of New York.*—It must be premised that the following statements are almost wholly based upon the Tables of Palæozoic Life which accompany this memoir. In Great Britain and in Europe generally, we have laid under tribute the accumulated labours of Murchison, Portlock, Phillips, De Verneuil, Salter, M'Coy, Sharpe, and others,—correcting the British portion in accordance with the admirable catalogue of Professor Morris, a work without which, in fact, these studies would have been impossible. But I am in an especial manner bound to acknowledge the invaluable assistance of Mr. J. W. Salter, Palæontologist to the Museum of Practical Geology. He has been so good as to revise most carefully my Table of the mineral habitats of the Silurian fauna of Wales and the adjacent English counties. So many have been his corrections and additions that this Table has become more truly his than mine. The Tables of the New York fossils are made up principally from the writings of James Hall, of Albany, appropriately denominated by Professor Sedgwick * "the great American Palæontologist." Numerous details have also been derived from the Reports of Conrad, Vanuxem, and Emmons, as well as from a recent publication of James Hall, on the *Brachiopoda* of certain parts of the United States.

My Tables of N. American Fossils are not completely on a level with the classification of the present day, and particularly in the *Brachiopoda*, *Lamellibranchiata*, and *Crustacea*; but I am happy in thinking that their defects do not affect results. De Verneuil and Agassiz have both personally compared the rich fossil collections of James Hall with his descriptions and nomenclature, and have amply testified to their general correctness. The Table which distributes the New York fossils into their respective sediments may be consulted, as containing a vast preponderance of reliable facts; but after all, in the sure expectation of future discoveries (not great, perhaps), and in the present scarcity of chemical analyses, this Table is only and simply approximate. In those rather numerous cases where the American geologists have given the general mineral character only, I have been guided by crystalline or other structure, by the presence of animals of well-known habitats, and by other collateral considerations. Ten or twelve years ago our highly esteemed fellow-member the late Daniel Sharpe thought it too early to obtain sound deductions from the fossils with which we were then acquainted; but since that time, the labours of Edward Forbes, Hall, Barrande, Morris, and Davidson, with many others, have put a new face on palæontological science; and after all, the question is not whether these tables are perfect, but whether they furnish useful truths. My persuasion is that they do: everything that care can accomplish has been bestowed upon them.

De la Beche, John Phillips, Elie de Beaumont, De Luc, Prony, and Constant Prévost; to these the reader is referred on points purposely avoided in the foregoing pages.

* Classif. Brit. Palæoz. Rocks, p. xcvii.

Probably there are undiscovered fossils in the sedimentary rocks of New York; but since an eager, enlightened, and extensive search has been going on for many years in districts both wild and under cultivation, and abounding in large and lofty sections, very great accessions cannot now be expected. James Hall will, however, soon favour us with many more Devonian *Zoophyta* and *Bryozoa*.

The relations between the sedimentary strata and their fossils are close. They at once tend to demonstrate the gradual burial, at all ages of growth, of the beings who lived on the spot, and to confirm in detail the great law announced some years ago by Constant Prévost, and very recently enforced by Agassiz *, that the Creator has always placed organic forms among physical conditions suited to their natures. The lower existences were intended to serve the higher. The habitation was prepared for the living sentient creature—not the creature for the habitation. To the sedentary animal was given the solid support of a rock; to the burrowing invertebrate, a loose sand; and so on. Fine examples of this abound in all palæozoic areas: those of New York and elsewhere will be mentioned in the sequel. Murchison† says that in certain *arenaceous* tracts of Russia, as also in the Scottish Old Red Sandstone, the organic remains are exclusively those of fish—locomotive, of course, and mostly carnivorous; but in calcareous districts of the same age similar fish are associated with molluscs, &c., the latter being only there able to exist. In like manner the sandstone of Marwood, in North Devon, contains a peculiar bed of the arenicolous *Cucullæa* and *Cypricardia*, because it was only on such beds that they could exercise their instincts; and in the slaty and gritty layers of Pilton and Brushford lie some remarkable Trilobites, together with the *Spirifer calcaratus*, not seen, or rarely, in the neighbourhood (John Phillips). A curious negative influence is exerted by serpentine in the cliffs of the islands about the Lizard Point, and in the Ægean Sea. In those local waters there is an almost total absence of Testacea, while the adjacent bays, with sides of marble, abound in animal life. Lake Superior, in like manner, possesses but few molluscs—chiefly on account of the very little limestone existing in the country the drainage of which it receives. But this want is supplied on the north side of the Lake by the great northern drift of Upper Silurian limestone, which is scattered far and wide, and has furnished materials for the calcareo-argillaceous silt which, with the debris of shells, now forms the bottom of Lake Superior. In parts where this drift is deficient, some of the freshwater molluscs, being lithodomous, are coated with a mosaic of very small bits of quartz and felspar. The influence of the mineral character of the sediment is conspicuously seen in the nature of the vegetable food and the shelter it provides—both acting in a marked manner on the number and kind of the animals, carnivorous and herbivorous, who dwell there.

We now present two Tables of great interest (Tables V. and VI.),

* Contributions to the Natural History of the United States.

† Geol. of Russia, &c., vol. i. p. 581.

being, in fact, "Dredging-Tables" of the Silurian seas of Wales with the adjacent English counties, and of the State of New York; in other words, they exhibit the mineral habitats of the old faunæ and floræ of those regions, as far as is at present ascertained. They gradually conduct the reader from the shores of the great sea of the time into the deeps of its remote centre, revealing its various populations as he passes through a succession of strata—first conglomeratic, then gritty, sandy, and argillaceous, until limestone more or less pure is reached; just as we find to obtain in seas at the present day. I only know of

TABLE. V.—*Exhibiting numerically, the Sedimentary Habitats of the Silurian Fauna and Flora of the State of New York.*

| Families and Orders. | Species, of known Habitats. | Non-calcareous Sediments. | | | | | | Calcareous Sediments. | | | | | | | Grand Total of appearances. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Siliceous Sandstone. | Argillaceous Sandstone. | Micaceous Argill. Sandstone. | Argillo-ferrug. Sandstone. | Iron-ore. | Total. | Calcareous Sandstone. | Calcareous Argillaceous Shale. | Argillo-calcareous Shale. | Siliceous Limestone. | Argillaceous Limestone. | Limestone. | Total. | |
| Plantæ | 31 | 5 | 18 | ... | ... | ... | 23 | 3 | 1 | 1 | ... | 5 | 1 | 11 | 34 |
| Annelida | 11 | ... | 2 | ... | 1 | ... | 3 | 1 | 4 | 1 | ... | 4 | ... | 10 | 13 |
| Zoophyta | 82 | ... | 3 | ... | ... | 2 | 5 | 2 | 5 | 17 | 2 | 44 | 9 | 79 | 84 |
| Crinoidea | 49 | ... | ... | ... | ... | ... | ... | ... | 8 | 27 | ... | 9 | 7 | 51 | 51 |
| Cystidea | 4 | ... | ... | ... | ... | ... | ... | ... | ... | 4 | ... | ... | ... | 4 | 4 |
| Crustacea | 61 | ... | 2 | 2 | ... | 3 | 7 | 2 | 9 | 10 | ... | 24 | 12 | 57 | 64 |
| Bryozoa | 68 | 1 | 4 | ... | ... | ... | 5 | 4 | 15 | 27 | 1 | 15 | 7 | 69 | 74 |
| Brachiopoda | 254 | 6 | 7 | ... | 7 | 4 | 24 | 3 | 19 | 40 | ... | 152 | 23 | 237 | 261 |
| Monomyaria | 44 | 1 | 4 | ... | ... | 1 | 6 | ... | 11 | 4 | ... | 14 | 11 | 40 | 46 |
| Dimyaria | 49 | 3 | 10 | ... | 1 | ... | 14 | 4 | 9 | 10 | ... | 14 | 6 | 44 | 58 |
| Gasteropoda | 94 | 4 | 2 | ... | ... | ... | 6 | 12 | 8 | 6 | 2 | 33 | 32 | 93 | 99 |
| Heteropoda | 23 | 1 | ... | ... | 1 | ... | 2 | 2 | 4 | ... | 1 | 13 | 4 | 24 | 26 |
| Pteropoda | 8 | ... | ... | ... | ... | ... | ... | ... | 2 | 2 | ... | 4 | 1 | 9 | 9 |
| Cephalopoda | 93 | 2 | 6 | ... | ... | ... | 8 | 3 | 7 | 7 | 2 | 56 | 20 | 95 | 103 |
| Total | 871 | 21 | 55 | 2 | 12 | 10 | 103 | 36 | 102 | 156 | 8 | 387 | 133 | 823 | 926 |

fossiliferous conglomerates and grits (Silurian) in Wales; but they may exist in New York. It is to be remembered that in these cases, according to Mr. Salter, the molluscs (creatures of later date) sought the conglomerates.

Although considerable similarity of aspect is presented by the eastern and western Silurian areas, as exhibited in Tables V.–VIII., and especially as regards the numbers and distribution of animal life, still we notice differences quite as considerable. This may be accounted for by the as yet much less perfect examination of the New York area, and by the very warrantable supposition that the creative force has been exercised in a different manner in the two districts. We observe that the calcareous or deep-sea sediments are much more fossiliferous than the arenaceous or shallow bottoms,—although not in the same proportion in our two districts,

Table VI.—*Exhibiting numerically the Sedimentary Habitats of the Silurian Fauna and Flora of Wales and the adjacent English Counties.*

| Classes, Families, and Orders. | Species, of known Habitats. | Non-calcareous Sediments. | | | | | | | Calcareous Sediments. | | | | | | Grand Total of Appearances. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Siliceous Conglomerate. | Siliceous Grit. | Siliceous Sandstone. | Argillaceous Sandstone. | Mudstone. | Carbonaceous Shale. | Total of Appearances. | Calcareous Sandstone (earthy Limestone). | Calcareous Argill. Shale. | Argillo-calcareous Shale. | Argillaceous Limestone. | Limestone. | Total of Appearances. | |
| Plantæ ......... | 12 | 1 | 3 | 8 | 1 | 1 | ... | 14 | ... | ... | ... | ... | ... | ... | 14 |
| Annelida ...... | 25 | 2 | 3 | 6 | 4 | 4 | ... | 19 | 5 | 13 | 7 | 3 | 2 | 30 | 49 |
| Amorphozoa... | 3 | ... | ... | ... | 1 | ... | ... | 1 | ... | ... | ... | 2 | ... | 2 | 3 |
| Zoophyta ...... | 81 | 5 | 4 | 4 | 17 | 2 | 2 | 34 | 25 | 16 | 19 | 54 | 7 | 121 | 155 |
| Crinoidea ...... | 69 | 1 | 1 | 4 | 5 | 12 | ... | 23 | 14 | 4 | 2 | 39 | ... | 59 | 82 |
| Crustacea ...... | 154 | 5 | 6 | 21 | 48 | 41 | 33 | 154 | 47 | 32 | 34 | 49 | 7 | 169 | 323 |
| Bryozoa ...... | 41 | ... | 1 | 1 | 8 | 11 | 9 | 30 | 11 | 3 | 7 | 23 | 1 | 45 | 75 |
| Brachiopoda... | 167 | 17 | 22 | 38 | 80 | 32 | 18 | 207 | 80 | 65 | 70 | 79 | 15 | 309 | 516 |
| Monomyaria | 22 | ... | 1 | 11 | 4 | 4 | ... | 20 | 9 | 9 | 3 | 6 | ... | 27 | 47 |
| Dimyaria ...... | 64 | ... | 4 | 17 | 33 | 13 | 2 | 69 | 24 | 24 | 5 | 3 | 1 | 57 | 126 |
| Gasteropoda... | 57 | 6 | 9 | 14 | 18 | 10 | ... | 57 | 23 | 15 | 10 | 23 | 4 | 75 | 132 |
| Heteropoda ... | 12 | ... | 2 | 7 | 8 | 5 | 2 | 24 | 8 | 6 | 3 | 2 | ... | 19 | 43 |
| Pteropoda...... | 11 | ... | 1 | 3 | 5 | 4 | ... | 13 | 3 | 8 | 2 | 4 | ... | 17 | 30 |
| Cephalopoda | 50 | ... | 1 | 6 | 17 | 20 | 3 | 47 | 15 | 22 | 11 | 19 | ... | 67 | 114 |
| Pisces ......... | 11 | 5 | 3 | 2 | 1 | 1 | ... | 12 | 3 | 3 | ... | ... | ... | 6 | 18 |
| Total ......... | 779 | 42 | 61 | 142 | 250 | 160 | 69 | 724 | 267 | 220 | 173 | 306 | 37 | 1003 | 1727 |

being as eight to one in New York, and two to one in Wales. The animal life of this period is most abundant in moderate depths, as indicated by limestone containing a good deal of alumina. *Annelida, Crustacea, Brachiopoda, Lamellibranchiata, Gasteropoda, Heteropoda,* and *Cephalopoda*—a vast series of existences—occupy almost every form of sediment; the same species occur, as we shall see, in very many. The *Plantæ,* both in New York and Wales, require further study. The majority of the North American forms, so denominated at present, will probably be resolved into the casts of the intestinal canals of great *Annelida* (Salter),—their contents, in fact, at the time of death more or less changed in mineral character. If so, we shall be justified, with Mr. Salter, in considering the Silurian system the especial *Annelid- or Worm-period*; for the size and numbers of these creatures appear to have then been larger by far than at any subsequent time. Judging from the sedimentary habitats of the *Crustacea, Brachiopoda, Dimyaria, Gasteropoda, Heteropoda,* and *Cephalopoda* of Table VI., the zones of marine life established for the present epoch by the lamented Professor Edward Forbes cannot be applied with rigour to the Silurian seas. We see that the *Monomyaria* and *Gasteropoda* are more deep-sea than littoral; and that *Heteropoda* abound in shallows and moderate depths, becoming almost extinct elsewhere. We see that the remains of fish are eminently littoral. Other interesting facts may be gathered by consulting the Tables.

We shall now enter into a few details on the organic relations of the great sedimentary elements—calcareous, argillaceous, and arenaceous, successively.

*a. Calcareous strata.*—A stratum highly charged with lime (but having little magnesia) usually abounds with *Testacea*; and they vary in number and perfection according to the greater or less admixture with other matters. When these strata contain alumina, we have the maximum of early palæozoic life. But if they become wholly carbonate of lime, comparative barrenness follows in Wales; for fossils only occur 37 times in pure limestone, that is, about $\frac{1}{10}$th as often as in argillaceous limestone, and forming $\frac{1}{46}$th part of Silurian life in Wales. In the New York Table of Habitats, a similar disposition prevails, the ratio in the former case being as one to three. With a more accurate Table, the deficiency of evidence of Silurian life in pure limestone will probably be yet more striking.

The *Pentamerus Knightii* of Aymestry is a fine example of the quick feeling of a mollusc (J. Phillips). If the rock lose its lime, and become altogether argillaceous, the animal disappears; but if, as at Sedgeley, the lime returns, with it also returns the mollusc. Or growth may be affected. Thus, among the *Brachiopoda, Terebratula princeps,* found near Mnienian (Bohemia), is, like *Phacops fœcundus,* double the usual size. So it is with the gasteropod *Natica* in that locality, and also with others*.

Barrande † finds that scarcely any two beds of limestone are equally capable of preserving organic remains; each layer and each spot sheds its own influence over the fossil. The envelopes of some *Testacea* are totally dissolved in certain calcareous masses; but not so in others. A red oxide of iron or a thin film of clay is a great preservative of the Trilobite: mere fineness of texture, as in the Bohemian schists, is not sufficient. Animal existence becomes suddenly multitudinous in the aluminous limestones of the New York group B (Trenton); and at about the same epoch in Wales a nearly equal abundance and variety of life burst upon our view, increasing in both hemispheres, on the whole, as the long succession of fossiliferous strata overlie each other. The *Annelida* of New York are calcaricolous, with three exceptions. In Wales also they are mostly in calcareous strata, but only two in pure limestone. Of

* Barrande, Syst. Sil. p. 297.

† *Op. cit.* p. 294.

sixty-eight *Bryozoa* of our western area, all but five are in calcareous beds here—principally in shales. The five alluded to are three species of *Graptolites* in argillaceous sandstone, *Retepora Clintoni* in siliceous sandstone, and *Fenestella tenuis* in the Clinton beds of iron-ore.

The 41 Welsh *Bryozoa* present only ten species strictly arenicolous, eleven inhabiting pure clay, and nine carbonaceous shale; the rest are in highly calcareous beds. Of the 82 species of *Zoophyta* of known matrix in the New York area, only five are met with in a non-calcareous rock. They are *Dictyolites Beckii, Discophyllum peltatum*, and *D.* sp. indet., in argillaceous sandstone, and *Catenipora escharoides* and *Phœnopora constellata* in the Clinton iron-ore.

The 81 Welsh *Zoophyta* are more freely distributed; but they are four times more numerous in calcareous strata than out of them.

The *Crinoidea* and *Cystidea* of New York wholly affect strata containing lime, especially when shaly. In Wales, this does not hold true; but nevertheless three-fourths of these fossil appearances are in calcareous strata.

The *Cystidea* abound in the Lower Silurian limestones of the Ottawa River, about Victoria; but none have been hitherto found in the Silurian beds of New York. Out of 323 appearances of Trilobites in Wales, nearly one-half are in strata destitute of lime. It is in argillaceous sandstone and in argillaceous limestone that they are very frequent (48 and 49 occurrences respectively). The proportion of arenicolous Trilobites in New York is as one to nine, the other and far larger portion being in argillaceous limestone and argillaceous shale, with twelve more in pure carbonate of lime—an unusual circumstance. The four *Crustacea* in purely argillaceous and arenaceous beds are *Homalonotus delphinocephalus* and *Olenus asaphoides* (both in argillaceous sandstone), *Agnostus pisiformis* (in the same stratum, but micaceous), and *Beyrichia lata* (in Clinton iron-ore).

Of 254 species of *Brachiopoda* in New York, of known matrix, only twenty-four are found in non-calcareous sediments; whilst in Wales the distribution is much more general, there being 207 appearances in the beds just spoken of, against 309 in the limestone-rocks. The reason of this may be that in Wales lime in small quantities pervades many sets of layers which are not classed as calcareous. In New York the appearances are most numerous in argillaceous limestone; in Wales, in Bala Limestone and argillaceous sandstone. Most of the genera of *Brachiopoda* furnish examples of arenicolous and argillicolous species. They are easily found on reference to the Tables.

In the New York area all the 44 *Monomyaria*, excepting six, are in highly calcareous sediments, eleven being in pure limestone. Four of the six above excepted are in argillaceous sandstone. In Wales, the *Monomyaria* appear 27 times in calcareous strata (never in pure limestone), and 20 times in arenaceous beds. We know the matrices of 49 *Dimyaria* in New York. These appear 44 times in lime-rocks (most numerously in the argillaceous), and 14 times in sandstone-rocks—chiefly in those of the Hudson-River group which contain alumina.

The Welsh *Dimyaria* (64 species) show themselves 57 times in calcareous deposits, mostly in the arenaceous limestone of Bala; while we find them 69 times in arenaceous muds with and without mica, and commonly of the Upper Ludlow period. We only see the deep-sea or limestone beds thus fail comparatively in three other cases in Wales—for instance, in the family *Plantæ* and the order *Heteropoda* and class *Pisces*. The *Cleidophorus planulatus* both of Wales and New York is in the same kind of argillo-arenaceous matrix. The nine appearances of *Pteropoda* in New York are principally in calcareous shales or argillaceous limestone, once in pure limestone; the eleven of Wales are pretty equally distributed over deep and shallow sea-bottoms. The New York *Gasteropoda* reside almost altogether in calcareous strata. Of the 94 species the mineral positions of which are known, six only are found elsewhere. It is different in Wales,—every sediment, except carbonaceous shale, possessing one or more of these fossils. Out of 132 appearances, 75 are in lime-rocks, and principally in arenaceous (Bala) and argillaceous limestone. Considering that the *Gasteropoda* are usually littoral, it is remarkable that the arenaceous deposits of New York should contain so few, because in that area the Silurian strata in which a siliceous or argillaceous sand is the governing ingredient are 3000 feet thick, neither the argillaceous shales (800 feet thick) nor limestones in their several varieties (1100 feet thick) attaining much more than one-third of that thickness. The explanation is to be found in the sandstones there being at the base of great or considerable epochs. In New York, 95 out of 103 appearances of the order *Cephalopoda* have calcareous habitats,—eight only, or $\frac{1}{13}$th of the whole, being met with in sandstone. In Wales, they are more equally distributed: one-third of all the appearances (114 in number) are in other than lime-rocks, seventeen of these being in argillaceous sandstone, and eighteen in mudstone. The arenicolous *Orthocerata* of New York are Mid-silurian, while in Wales two-thirds are Upper Silurian. In both countries they are found in beds containing mica disseminated in small scales.

*b. Argillaceous strata.*—There may be in New York fossiliferous strata of the Silurian age which are pure clay or mudstone; but I know of none. In Wales, 160 *Testacea* are found in mudstone, and more especially the *Brachiopoda*, *Dimyaria*, and *Cephalopoda*, also the *Crustacea*.

In abundance of fossils, argillaceous strata stand next to the calcareous; and when lime and alumina meet together in certain proportions, the Invertebrate population is extraordinarily great.

The *Graptolites* of New York (16 in number) adhere closely to strata abounding in clay, almost all of them being in the Hudson-River group. Four are in argillaceous sandstone, and one in argillaceous limestone (Trenton group, Hall). The *Graptolites* of Wales are most of them in mudstone and carbonaceous shale. Of the 51 appearances of *Echinodermata* in New York, thirty-five are in shale, usually very aluminous; but in Wales there are but six out of 82 appearances so placed,—a discrepancy not difficult of explanation. Of the 84 Zoophytal appearances, of known matrix, in New York, only twenty-two are in calcareo-argillaceous or argillo-calcareous shale, this order of creatures frequenting especially the deep seas. Of 155 appearances of Zoophytes in Wales, thirty-five only are in the above-mentioned shales, and thirty-four in non-calcareous habitats. Five out of seven of the New York *Tentaculites* are in argillaceous shale, in which also the *Annelida* of Wales are prevalent. One-fourth of the *Brachiopoda* of New York are in calcareo-argillaceous or argillo-calcareous shales, and about one-half of those of Wales,—the proportion of those in the former country, with the sedimentary relations of which we are acquainted, to those of the latter, being nearly as three to two—a fact due to their

Table VII.—*Species-Life, numerically, as appearing exclusively in Calcareous or Non-calcareous habitats in New York and Wales.*

(Reduced from Tables V. and VI.)

| Families and Orders of the Fossils. | New York. Appearances. | | Wales. Appearances. | |
|---|---|---|---|---|
| | In Calcareous Beds. | In Non-calcareous Beds. | In Calcareous Beds. | In Non-calcareous Beds. |
| Plantæ | 11 | 23 | ... | 14 |
| Annelida | 10 | 3 | 30 | 19 |
| Amorphozoa | ... | ... | 2 | 1 |
| Zoophyta | 79 | 5 | 121 | 34 |
| Crinoidea and Cystidea | 51 | ... | 59 | 23 |
| Crustacea | 57 | 7 | 169 | 154 |
| Bryozoa | 69 | 5 | 45 | 30 |
| Brachiopoda | 27 | 24 | 309 | 207 |
| Monomyaria | 40 | 6 | 27 | 20 |
| Dimyaria | 44 | 13 | 57 | 69 |
| Gasteropoda | 93 | 6 | 75 | 57 |
| Heteropoda | 24 | 2 | 19 | 24 |
| Pteropoda | 9 | ... | 17 | 13 |
| Cephalopoda | 95 | 8 | 67 | 47 |
| Pisces | ... | ... | 6 | 12 |
| Total | 823 | 102 | 1003 | 724 |

very different extent. The *Lamellibranchiata* of New York and Wales are a tolerant race, and inhabit freely the argillaceous shales. The New York *Cephalopoda* are not so fond of argillaceous strata as are those of Wales. In this last district they are very generally diffused.

*c. Arenaceous strata.*—The strata which consist principally of siliceous sand are poor in fossils; but they become richer on the addition of clay or lime. Several marine plants (?) occupy the Middle Silurian sandstones of New York, and in prodigious quantities. Few *Bryozoa*, *Zoophyta*, *Brachiopoda*, &c., and no Crinoids, are seen here in New York. They are more plentiful in the arenaceous strata of

Wales, especially the *Brachiopoda*—partly, as has already been said, from a small but general infiltration of lime among the sediments of the latter region.

*d. Fossils in Calcareous and in Non-calcareous strata.*—The summaries contained in Tables VII. and VIII. will give much additional information. They have been carefully prepared from the general Tables of matrices in the New York and Welsh basins.

Table VII. shows the number of fossils which have exclusively either calcareous or non-calcareous habitats. The areas of New York and Wales being so different in size and so remote from each other (the flora likewise not being the same), we do not expect to find in them the same number of fossils; but we are interested in observing a general similarity of matrix and of numerical proportions in all the orders of animal life until we come to the *Lamellibranchiata*, *Gasteropoda*, and *Cephalopoda*. Among these we find the fossils in non-calcareous beds greatly multiplied in Wales,—so much so as to be in *Dimyaria* in the ratio of sixty-nine to fifty-seven calcaricolous, and in *Heteropoda* as twenty-four to nineteen. Table VIII. exhibits the proportions of species-life as found in the sedimentary

TABLE VIII.—*Species-Life, numerically, as appearing in the Sedimentary Habitats in New York and Wales.*

(Reduced from Tables V. and VI.)

| | Silurian Sediments. | Fossils, by Species. (Appearances). | | | |
|---|---|---|---|---|---|
| | | NEW YORK. | | WALES. | |
| Non-calcareous. | Siliceous Conglomerate ...... | ... | | 42 | |
| | Siliceous Grit .................. | ... | | 61 | |
| | Siliceous Sandstone ......... | 25 | | 142 | |
| | Argillaceous Sandstone ...... | 67 | | 250 | |
| | Iron-ore ........................ | 10 | | ... | |
| | Mudstone ..................... | ... | | 160 | |
| | Carbonaceous Shale ........ | ... | | 69 | |
| | | — | 102 | — | 724 |
| Calcareous. | Calcareous Sandstone......... | 36 | | 267 | |
| | Calcareo-argillaceous Shale | 102 | | 220 | |
| | Argillo-calcareous Shale ... | 156 | | 173 | |
| | Siliceous Limestone ......... | 8 | | ... | |
| | Argillaceous Limestone...... | 387 | | 306 | |
| | Limestone ..................... | 133 | | 37 | |
| | | — | 822 | — | 1003 |
| | Total ......... | | 924 | | 1727 |

beds of the two countries. It tells us that their fossils, though harmonizing in important respects, differ greatly in their numbers as occupants of the same sediment. Thus New York at present is supposed to have no Silurian fossils in siliceous conglomerate or grit; while Wales possesses many, and indifferently in all the stages of the system. In no case is this diversity more striking than in those of calcareous sandstone and of pure limestone, because the ages and conditions of deposit were different in the two countries. In New York this kind of sandstone occurs at the very dawn of life, or after considerable disturbances, or it is impregnated with magnesia or salt. We remark also that only two fossils occur in micaceo-siliceous sandstone here; while sixty at least (principally *Dimyaria* and *Gasteropoda*) occur in that rock in Wales, where we meet with micaceous and hardened strata in far greater abundance than in New York. The frequent occurrence of volcanic overflows in Wales might prepare us for this, such events *possibly* producing the mica by metamorphosis; at all events it is supposed that mica was formed more or less after deposition. The arenaceous limestone, poor in middle North America, abounds in evidences of life in the Bala group of Wales, which corresponds with the Trenton group of New York. Table VIII. shows also the remarkable and unexpected fact, as elicited by the careful investigations of Mr. Salter, that simple limestone contains little more than 2 *per cent.* of all the fossil appearances in Wales,—New York, after diligent search, yielding 14 *per cent.* This is contrary to the supposed favourable properties of the carbonate of lime; but it in reality depends on the comparative powerlessness of any single substance to maintain life.

We see in the same Table, that Welsh mudstone or pure clay contains 11 *per cent.* or nearly, by which it would seem that there is the occasional presence of lime. With further examination, most probably the 14 *per cent.* of life-evidence in pure limestone, as regards New York, will be sensibly lessened.

Tables V. and VI., which distribute the Silurian fossils of our two areas into their several sediments, are not without considerable interest. They are in fact palæozoic "dredging-tables." We see the fossils of both usually affecting the same sediments, and in tolerably proportionate numbers—if few in New York, then few in Wales; and contrarywise, while some species are seen only by ones and twos in certain strata, others (*Crustacea*, &c.) fill up nearly every group. The depths (shallow, middle, or great) assumed in the one basin are observed in the other, with occasional deviations on account of local causes. The *Plantæ* are inserted provisionally. The *Zoophyta*, *Crinoidea*, and *Cystidea* are seldom or never in shallows; for most of them require still water.

*e. Divergence.*—We have now to consider briefly a subject which, perhaps, has not been sufficiently attended to, although curious in itself and not without several important bearings—upon geographic distribution, for example, and on the recurrence or vertical range of animal life. It is this: a very large proportion of the Silurian fauna is not constant to one form of sediment, but deviates into others, and these not necessarily on the same horizon. It is noticed by Alcide D'Orbigny* in the following words:—"The same fossil fauna is found in the same geological horizons in beds of entirely different mineral character." This group of organic remains may be called "divergents,"—not using the better term "aberrants," because it has been already appropriated.

By the New York Table of Fossil Habitats (Table V.), we find that

* Elém. Paléont. vol. i. p. xxxiv.

the proportion of "divergents" there to the whole of the Invertebrata of which the sedimentary position is known is only about one-ninth,—eighty being in two beds, ten in three, and one in four beds: the *Dimyaria*, *Gasteropoda*, and *Crustacea* are the most divergent; *Crinoidea* and *Zoophyta* the least so. But this, I feel persuaded, is an inadequate estimate of the true "divergence" of this American area, although the best attainable at present; for the more complete examination of the same or equivalent system in the Welsh area shows a far larger number of divergents,—779 species changing their habitats 382 times—a condition of things, we may note, which bespeaks great vital force.

Table IX.—*Exhibiting the Number of Beds into which the Silurian Fossils of Wales diverge from their first or original habitat.*

| Fossils. | Species, of known Habitats. | Number of Beds into which Divergence takes place. | | | | | | | | | | | Proportion of the whole. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X | IX | VIII | VII | VI | V | IV | III | II | I | Total Diverg. | |
| Brachiopoda ... | 167 | 1 | 3 | 1 | 2 | 2 | 15 | 17 | 19 | 22 | 31 | 113 | $\frac{2}{3}$ |
| Crustacea ...... | 154 | ... | 2 | 1 | 1 | 5 | 5 | 4 | 15 | 16 | 21 | 70 | $\frac{1}{2}$ |
| Dimyaria ...... | 64 | ... | ... | ... | ... | ... | 1 | 1 | 5 | 7 | 21 | 35 | $\frac{7}{12}$ |
| Gasteropoda ... | 57 | ... | ... | ... | ... | 3 | ... | 1 | 10 | 5 | 15 | 34 | $\frac{4}{7}$ |
| Zoophyta ...... | 81 | ... | 1 | ... | 1 | 1 | 2 | 3 | 3 | 6 | 12 | 29 | $\frac{1}{3}$ |
| Cephalopoda ... | 50 | ... | ... | ... | ... | 1 | 2 | 3 | 4 | 6 | 9 | 25 | $\frac{1}{2}$ |
| Bryozoa ......... | 41 | ... | ... | ... | 1 | ... | 1 | 1 | 2 | 5 | 8 | 18 | $\frac{5}{11}$ |
| Monomyaria ... | 22 | ... | ... | ... | ... | 1 | 1 | ... | 4 | 1 | 7 | 11 | $\frac{1}{2}$ |
| Heteropoda ... | 12 | ... | ... | ... | 1 | 1 | ... | 1 | 2 | 3 | 3 | 11 | $\frac{11}{12}$ |
| Echinodermata | 69 | ... | ... | ... | ... | ... | ... | 1 | ... | 3 | 5 | 9 | $\frac{2}{15}$ |
| Annelida ...... | 25 | 1 | ... | ... | ... | 1 | ... | ... | 1 | 3 | 2 | 8 | $\frac{1}{3}$ |
| Pteropoda ...... | 11 | ... | ... | ... | ... | ... | 1 | 1 | ... | 2 | 4 | 8 | $\frac{2}{3}$ |
| Pisces............ | 11 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 6 | 7 | $\frac{2}{3}$ |
| Plantæ ......... | 12 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | $\frac{1}{12}$ |
| Total ...... | 776 | 2 | 6 | 2 | 6 | 15 | 28 | 33 | 65 | 81 | 144 | 379 | |

Table IX., which is here introduced, will show the extraordinary number of beds occupied by the same species,—a circumstance which becomes of great import when we remember that these beds represent certain depths of water, and that therefore the bathometrical zones of life were not so strictly adhered to in Silurian times as at present, although their limits are even now loosely and variously defined. A rather high and equably diffused temperature then permitted the animals to wander into different depths, and to rest at any spot which supplied their several needs. One half, at least, of the Invertebrates were predacious, and therefore in some measure independent of the flora, which must have changed with the sediment; and, on inquiry, we discover that the freest and most numerous divergents are carnivorous, namely the *Cephalopoda*, *Heteropoda*, *Crustacea*, and certain *Zoophyta* and *Brachiopoda*. This Table follows the animal life of the period into its greater divisions, and points out the large proportion which, in almost all cases, divergency maintains to constancy. It shows also that the weaker the vitality the less the divergency, as might have been expected. Plants probably never diverge; the one (Lycopodiaceous spores) said to do so is supposed to be a land-plant, and anyhow only occurs in finer or coarser forms of the same sediment. This Table further shows that the species enjoying the widest geographical range are the most divergent.

For the purpose of more closely observing the mineral relations of the fossils, the sediments (habitats) may be classed under two heads —the "similar" and the "dissimilar," each suiting particular fossils. In the "similar" the characteristic ingredient remains predominant, varying proportions of other minerals being introduced, as when pure carbonate of lime becomes arenaceous or argillaceous. In the "dissimilar" the characteristic ingredient disappears, or nearly so, and is replaced by other minerals in varying quantities. We are therefore not surprised to find that in Wales the number of "divergents" entering similar habitats is 224, while those passing into the "dissimilar" is 158. In New York the difference is still more striking, the proportion being 68 to 30. The first or original habitat must be the oldest; and it would be interesting to discover the circumstances under which the transit from thence has been made; but such an inquiry is as yet in its infancy, and would involve details on the habits of animal life, and on the effects of oscillations in level, altogether out of place here. We shall only say that many appear first in the sandstones of early Silurian times, and ascend from thence into the muds and limestones of the eastern and western hemispheres. We see this in *Favosites alveolaris*, *Stenopora fibrosa*, *Cornulites serpularius*, *Beyrichia Klœdeni*, *Athyris reticularis*, &c.

Calcareo-argillaceous shale and calcareous sandstone seem to have in Wales the most frequent organic relations with other sediments. Speaking now of Welsh palæozoic life, we find that the *Brachiopoda* are very divergent (see Table VI., Mineral Habitats). *Orthis elegantula* occupies eleven habitats, and *Strophomena depressa* ten. Much the same may be said of the *Crustacea*, while the *Zoophyta*, with a few exceptions (*Favosites alveolaris* in 10 habitats), do not often diverge. The *Lamellibranchiata* have considerable force in this respect, but, with the exception of *Pterinœa retroflexa*, do not enter very many beds. The same may be affirmed of the *Gasteropoda*,—*Cyclonema crebristria*, *Euomphalus funatus*, and *Platyschismus helicites*, however, each frequenting seven habitats. The *Heteropoda* are extremely divergent, *Bellerophon bilobatus* being found in eight matrices. The *Echinodermata* seldom diverge. One Annelid (*Cornulites serpularius*) is met with in ten separate beds; but the rest seldom travel out of their first bed.

After a very few necessary words on the divergency of the fossil species of the New York Basin, in addition to what has already been said, we shall content ourselves with producing Table X., intended to show the comparative divergency of the fossil species of Wales and New York, as far as at present known; it is hoped that further details will be unnecessary. The fossil species of New York, unlike some of those in Wales, are confined to few habitats, —only one, *Spirifer radiatus*, being found in four beds. They are plentiful in three, and still more common in two. Further research may alter this.

TABLE X.—*Giving a Comparative View of the Divergents of Wales and of New York.*

| Fossils. | Wales. | | New York. | |
|---|---|---|---|---|
| | Total Species, of known Habitats. | Divergents. | Total Species, of known Habitats. | Divergents. |
| Plantæ | 12 | 1 | 33 | 2 |
| Annelida | 25 | 8 | 11 | 2 |
| Crinoidea | 69 | 9 | 49 | 3 |
| Zoophyta | 81 | 30 | 81 | 6 |
| Bryozoa | 41 | 18 | 67 | 10 |
| Crustacea | 154 | 70 | 61 | 13 |
| Brachiopoda | 167 | 114 | 225 | 18 |
| Monomyaria | 22 | 11 | 44 | 4 |
| Dimyaria | 64 | 35 | 49 | 10 |
| Gasteropoda | 57 | 34 | 94 | 10 |
| Heteropoda | 12 | 10 | 23 | 3 |
| Pteropoda | 11 | 8 | 8 | 2 |
| Cephalopoda | 50 | 26 | 96 | 10 |
| Pisces | 11 | 6 | ... | .... |
| Total | 776 | 380 | 841 | 93 |

*f. Recurrence.*—The transition from the subject of "divergence" to that of "recurrence," or the vertical range of life, is easy and natural. We shall treat of the latter first as found in the Silurian, and secondly in the Devonian, system of the State of New York and Wales.

It is hoped that the statements which follow will not be destitute of interest. They rest mainly on two published tables:—Table I., Quart. Journ. Geol. Soc., vol. xiv. p. 399; and the Table of the Silurian Fossils of Britain, in Appendix A, in Sir Roderick Murchison's 'Siluria,' 2nd edition.

Throughout these pages, the word "recurrence" will be used in the sense of reappearance in one or more epochs. It was introduced, I believe, by our present learned President, to whom we owe many of our happiest geological expressions. "Vertical range" is another phrase used to denote progress from epoch to epoch. Not to recur renders any given form typical, or "restricted" in the language of James Hall; and thus it becomes of high value, as denoting a certain geological period: but typical fossils are not marked, as far as I know, by great structural differences. All the orders, and many of the genera, contain numerous examples of both typical and recurrent life. Still distinctions may be pointed out. Animals, especially the divergent, are enabled to recur by the hardiness of their constitution. Many are continued in existence by their numbers and diminutive size; others are washed dead into newer sediments, and are therefore not really recurrent. Those animals, on the contrary, which have weak vital powers, such as the *Echinodermata, Zoophyta,* and *Bryozoa,* scarcely excepting *Graptolites,* have little or no vertical range; and others, because they are fixed or sedentary. These remarks apply to all known Silurian regions, their recurrents being often identical. One very important observation should be made, and to the effect that, when recurrence in contiguous sedimentary strata exceeds a certain limited amount, such strata cease to belong to different epochs, and must be united, as has been done in Wales by Sir Roderick Murchison.

Where there is much recurrency, we may infer that in such a series of groups the conditions of the ocean were nearly stationary, and that the mutual relations of sea and land remained much the same; for altered conditions are the great obstacle to recurrence. On this subject, I shall only at present notice, as occasioning these alterations, the secular oscillations and sudden uplifts which have always from time to time created new coast-lines, thrown up banks of mud and sand, and have changed the direction and force of currents. These currents may bring with them colder or warmer, turbid or heavily loaded waters; they may sweep away beds of marine plants with their inhabitants, and introduce new life; or they may bury old sea-bottoms beneath a thousand feet of shingle and conglomerate.

Table XI.—*Number of Silurian Species recurrent in one or more sets of strata.*

| No. of Groups in which recurrence takes place. | | I | II | III | IV | V | VI | VII | VIII | Total. |
|---|---|---|---|---|---|---|---|---|---|---|
| Recurrent Fossils. | New York... | 93 | 16 | 6 | 1 | 1 | 1 | ... | 3 | 121 |
| | Wales......... | 129 | 51 | 14 | 2 | ... | ... | ... | ... | 196 |

By intermixing fossils which originate in different horizons, recurrency produces a difficulty in determining the dates of such horizons; but this may usually be lessened by the presence of other forms, and by the nature of the sediment. Any given species occupies, as a general rule, the same horizon in all parts of the globe. A fossil which is Upper Silurian in New York is the same in Scandinavia or Wales, as we learn from the Tables of De Verneuil and D'Archiac (Geol. Trans. 2 ser. vol. vi.), and from my Table of the fossils common to New York and Europe. This is a state of things due to the absence of isothermal lines until very recently in the world's history. Some exceptions to this rule I have met with without any regular search; but they may arise from recurrence, may belong to passage-beds, or the specimen may have been transported in the dead state. They deserve notice because they suggest the interesting idea of migration from older into newer beds, and, in successive generations, from place to place, through enormous periods of time. In the great freedom of Molluscan movements in primæval epochs, and in almost infinitely slow oscillations of level, may be recognized the probable instruments of migration. We might thus learn the true birth-place of species; and a Bala or Trenton Brachiopod be thus ascertained to be the ancestor of an individual buried in the Wenlock or Niagara of India.

TABLE XII.—*A numerical List of the Recurrent or Non-typical Fossils of the Silurian System of New York.*

| Thickness. | Silurian Sections of New York. | Total Fossil Appearances. | Plantæ. | Incertæ Sedis. | Zoophyta. | Bryozoa. | Crinoidea. | Brachiopoda. | Monomyaria. | Dimyaria. | Crustacea. | Gasteropoda. | Cephalopoda. | Pteropoda. | Annelida. | Total Recurrents. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet. | | | | | | | | | | | | | | | | |
| 30 | Upper Pentamerus Limestone | 25 | ... | ... | ... | ... | 1 | 6 | 2 | ... | ... | 1 | ... | ... | 1 | 11 |
| 40 | Delthyr. Sh. Limest. | 60 | ... | ... | ... | ... | ... | 12 | 1 | ... | ... | ... | ... | ... | 1 | 14 |
| 60 | Lower Pentamerus Limestone | 19 | ... | ... | ... | ... | 1 | 6 | 3 | ... | 1 | 1 | ... | 1 | ... | 13 |
| 100 | Waterlime Group | 14 | ... | ... | 1 | ... | ... | 3 | ... | ... | 2 | ... | ... | ... | ... | 6 |
| 1000 | Onondaga-Salt Group | 29 | ... | ... | 1 | ... | ... | 2 | 1 | ... | ... | ... | 1 | ... | ... | 5 |
| 4 | Coralline Limestone of Schoh. | 40 | ... | ... | 3 | ... | ... | 3 | ... | ... | 1 | 1 | ... | ... | ... | 8 |
| 240 | Niagara Rocks | 180 | ... | ... | 5 | 2 | 3 | 15 | 2 | 1 | 7 | 1 | 2 | ... | ... | 36 |
| 1200 | Clinton Rocks | 141 | ... | ... | 3 | 2 | 3 | 10 | 2 | ... | 5 | 3 | 4 | ... | ... | 32 |
| | Medina Sandstone | 21 | ... | ... | 1 | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | ... | 3 |
| | Oneida Conglomerate | ? 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 650 | Hudson-River Group | 103 | ... | ... | 2 | 3 | 3 | 14 | 1 | 5 | 6 | 5 | 6 | ... | 2 | 47 |
| 200 | Utica Slate | 46 | ... | ... | 1 | 5 | 3 | 15 | 2 | 1 | 3 | 3 | 3 | ... | ... | 33 |
| 350 | Trenton Limestone | 256 | ... | ... | 3 | 3 | 2 | 16 | 1 | 5 | 13 | 6 | 3 | ... | 2 | 54 |
| 30 | Birdseye Limestone | 24 | ... | ... | 2 | 1 | 1 | 1 | ... | ... | 1 | 5 | ... | ... | ... | 11 |
| 100 | Chazy Limestone | 65 | ... | ... | 1 | 1 | 1 | ... | ... | 1 | 1 | 3 | 2 | ... | ... | 9 |
| 700 | Calciferous Sandstone | 19 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | 1 |
| | Potsdam Sandstone | 6 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | Total | 1048 | ... | ... | 23 | 17 | 18 | 103 | 15 | 13 | 40 | 31 | 22 | 1 | 6 | 280 |

Recurrence, we repeat, is a measure of the tenacity of life possessed by an animal — of viability, or a capacity for enduring changes of food, shelter, temperature, and such-like. It is also the measure of connexion and mineral similarity between strata. It contributes a marked feature to all palæozoic systems, being a bond of union throughout a long chain of parts—a living nexus, which, beginning with the earliest sedimentary bed of the Silurian system, passes upwards and combines the Silurian, Devonian, and Carboniferous rocks into one vast whole. For the moment we leave the Cambrian system out of consideration. Granting the great importance of recurrence, we observe that the animals so endowed were in the minority, being only 121 in 903, or $\frac{2}{13}$ths, for New York, and 196 in 797, or nearly $\frac{1}{4}$th, for Wales and Siluria. In by far the majority of cases the vertical range is short, and confined to one act of reappearance, as may be seen in Table XI., in which the upper line represents the number of groups or sections inhabited by the fossils enumerated in the lower lines. Thus, in New York 93 fossils recur once, 16 twice, and so on.

In the above Table, the numerical differences, as regards the country, are more apparent than real. They much depend on the smaller subdivisions employed in New York,—19 in that State, and only 7 in Wales. Recurrence in most instances taking place in contiguous groups, the same species is apt to be counted twice, from the occasional difficulty of determining the true terminal planes of each group. American authors unite with those of all other countries in testifying to the great mortality occurring at the end of the successive epochs, whether in Europe, America, or elsewhere. The useful Table XII. places this fact in a striking point of view for the Silurian system of New York. It is intended to show, with some exactness, that the specimens common to the various epochs or sections are usually few in comparison with the whole fauna of the period, and that even the swarming life of Trenton Limestone and Niagara rocks mostly perished, never to return.

Many useful observations may be made on this Table; but as most of them are obvious and others will be made afterwards, we shall here abstain, excepting on two points. Utica Slate, which has but few fossils of its own, contains an unusual number of such

TABLE XIII.—*Exhibiting the Typical and Recurrent Fossils of Wales, with their Ratios.*

| Fossils. | Typical. | Recurrent. | Ratio. | Fossils. | Typical. | Recurrent. | Ratio. |
|---|---|---|---|---|---|---|---|
| Plantæ ......... | 12 | 1 | $\frac{1}{12}$ | Monomyaria... | 15 | 7 | $\frac{1}{2}$ |
| Amorphozoa | 1 | 0 | 0 | Dimyaria ...... | 53 | 13 | $\frac{1}{4}$ |
| Zoophyta ...... | 56 | 28 | $\frac{1}{2}$ | Gasteropoda... | 40 | 14 | $\frac{1}{3}$ |
| Bryozoa ...... | 39 | 10 | $\frac{1}{4}$ | Heteropoda ... | 8 | 5 | $\frac{5}{8}$ |
| Crinoidea ...... | 76 | 1 | $\frac{1}{76}$ | Pteropoda ... | 7 | 3 | $\frac{3}{7}$ |
| Annelida ...... | 23 | 5 | $\frac{2}{11}$ | Cephalopoda | 37 | 15 | $\frac{2}{5}$ |
| Crustacea ...... | 131 | 32 | $\frac{1}{4}$ | Pisces ......... | 9 | 2 | $\frac{2}{9}$ |
| Brachiopoda | 107 | 59 | $\frac{4}{7}$ | | | | |

as are found in other epochs, particularly in the two contiguous, below and above. The *Brachiopoda* furnish the most numerous links of connexion, because this order generally has great viability. Further research will undoubtedly discover many more recurrent fossils in the Lower Helderberg series.

Table XIII. sets forth the ratio of recurrent fossils to typical in

Wales, as grouped in orders. This little Table tells us that *Plantæ*, *Annelida*, *Crinoidea*, and *Pisces* are the most tenacious of their original sea-bed, and that *Brachiopoda*, *Heteropoda*, *Zoophyta*, and *Monomyaria* are the most discursive. We furthermore infer from this Table that the typical fossils of Wales are three times the number of the recurrent (as 604 to 195), and that the typical of each order are always in excess. Among the Crinoids there is only one recurrent—the *Periechocrinus moniliformis* *.

The next Table (XIV.) gives the proportions of typical to recurrent species as they exist in the different stages of the Silurian rocks of New York and Wales. We see from this Table, that the fossils of the lower and middle Silurian stages of New York display nearly the same amount of vertical range, but the upper stage sensibly less,—and this partly from the proximity of a new and dissimilar condition of beds in what is called the Devonian system. In Wales, the vertical range is greater than in New York, and is most remarkable in the middle stage.

*g. Recurrence of Orders and Genera.*—Although but few species enjoy repeated recurrence—only 67 in Wales, and 28 in New York (see Table XI.),—most of the orders and genera (the *Zoophyta* and *Bryozoa*, for instance) occupy very many successive groups of strata. By an inspection of the general Tables of the fossils of New York and Wales, the student may so easily verify these facts for himself, that we shall not put the results here in a tabular form. We also notice many instances in which the orders and genera of these two distant countries are similar in the number, great or small, of the epochs they occupy: and many more examples of this perfect or proximate agreement would be found, were their respective fossils more in common; but New York abounds in special or regional forms. Table XV. exhibits in a striking manner the great similarity

Table XIV.—*Silurian Species in Wales and New York.*

| Silurian Stages. | New York. | | | | Wales and Siluria. | | | |
|---|---|---|---|---|---|---|---|---|
| | Typical. | Recurrent. | No. of First Appearances of Recurrents. | Proportion of Recurrents to Typical. | Typical. | Recurrent. | No. of First Appearances of Recurrents. | Proportion of Recurrents to Typical. |
| Upper ...... | 277 | 45 | 20 | ·166 | 316 | 113 | 40 | ·29 |
| Middle ...... | 127 | 25 | 28 | ·21 | 60 | 117 | 55 | ·257 |
| Lower ...... | 386 | 71 | 65 | ·24 | 243 | 63 | 63 | ·32 |

* The student can easily draw up a similar Table for the Silurian Fossils of New York, from Table I., Quart. Journ. Geol. Soc. vol. xiv. p. 399.

which exists in the recurrent power of orders and genera common to New York and Wales. The group-arrangement employed is that in use previous to the publication of the second edition of Sir R. Murchison's 'Siluria.'

A very interesting set of recurrents are those which escape from the lower Silurian of New York into the upper, by passing through or beneath the disturbances which, to a certain extent, occurred during the middle stage; but this subject has been sufficiently treated of in Quart. Journ. Geol. Soc. vol. xiv. p. 450, &c. I shall not prolong my remarks on the recurrent fossils of the Silurian basins of New York and Wales, but shall pass on to a brief consideration of vertical range in the Devonian system of the former.

*h. Recurrents of the Devonian System of New York*.*—In treating of this portion of our subject, we meet with several discouragements. The palæontology of this system in New York has not yet been fully opened to us. Sufficiently acquainted with its mineral characters,

TABLE XV.—*Exhibiting the great similarity in Recurrent Power of Fossils common to New York and Wales.*

| New York. | | Wales. | |
|---|---|---|---|
| Orders and Genera. | No. of Groups. | Orders and Genera. | No. of Groups. |
| Holopæa, Littorina; Raphistoma, Lyrodesma; Phragmoceras, Turbo | 1 | Holopæa, Littorina; Raphistoma, Cyrtoceras; Cypricardia | 1 |
| Pterinea, Orthonota; Nucula, Cleidophorus; Lituites, Cyrtoceras | 2 | Pterinea, Orthonota; Phragmoceras, Capulus; Ambonychia, Sanguinolites | 3 |
| Ambonychia, Capulus; Conularia, Cypricardia | 3 | Conularia | 4 |
| Euomphalus | 4 | Modiolopsis, Echinodermata | 5 |
| Pentamerus | 5 | Lingula, Spirifer; Nucula, Murchisonia; Turbo, Lituites | 6 |
| Annelida, Modiolopsis; Bellerophon, Cornulites | 6 | Avicula | 7 |
| Bryozoa, Echinodermata | 7 | Atrypa, Cleidophorus; Pentamerus, Bellerophon, Euomphalus | 8 |
| Lingula, Murchisonia | 8 | Annelida, Orthoceras | 9 |
| Orthis, Orthoceras | 9 | Zoophyta, Bryozoa; Leptæna | 10 |
| Leptæna, Spirifer; Avicula, Trilobites | 10 | Orthis | 11 |
| Zoophyta | 11 | Trilobites | 12 |
| Atrypa | 13 | | |

we have much to learn as to its fossils; but still of these we are in possession of the useful number of 418. Further, there are but

* For Table of Devonian Recurrents, see Q. J. G. S. vol. xiv. p. 424.

few Devonian strata in Wales. Although beautifully developed in the south-west of England, the system has not been minutely and systematically described, notwithstanding the labours of Phillips, Murchison, Austen, Sharpe, and others; we must therefore, when necessary, compare the Devonian life of New York with that of the Rhine as catalogued and commented upon by De Verneuil and D'Archiac (Geol. Trans. 2 ser. vol. vi.). In many phases and habitudes the palæontology of the Devonian system is only that of the Silurian continued, but marked by new forms and an ever-increasing abundance of specific life. In New York, sixty-two Devonian species are recurrent out of the whole 418, or nearly one-seventh; and therefore double the proportion observed in the Silurian system of that basin. Thirty-eight species recur but once, twelve but twice; and the rest are scattered and few. This is as we found it in the Silurian of New York, and indicates that the vertical range is short. Twenty-three of these recurrents are of Silurian origin,—namely four from Lower Silurian, seven from Middle Silurian, and ten from Upper Silurian, as is seen in Table VIII., Quart. Journ. Geol. Soc. vol. xiv. p. 424. This establishes a most important fact—the existence of a continuous chain of organic life from one system to another in the western hemisphere. Thirty of the recurrent Devonian fossils are *Brachiopoda*; seven are *Aviculæ*, five are *Zoophyta*; and the rest are principally *Gasteropoda*. In one remarkable particular, the mode of recurring differs from that in the Silurian strata—namely in the animal only reappearing in the nearest stratum of a similar mineral character to that in which it is first seen. The Corniferous Limestone and the Hamilton and Chemung groups are often thus associated; and so are Marcellus Shale and Genesee Slate. Recurrence was more plentiful in the Devonian system of Europe than in that of New York. As research in the latter region adds to the general number of species, the probability at present seems to be, that the proportion of recurrents will in future diminish, because the principal discoveries will lie among animals either sedentary or of low vitality. I do not attempt to trace the fossils of the New York Devonian into the Carboniferous system of Pennsylvania, close at hand, for want of materials. An examination of the valuable Catalogue of the Rhenish Devonian Fossils, above referred to, presents to us some grand exhibitions of the vital processes of the palæozoic period, of comparative repose for unnumbered ages, and of extraordinary longevity of species. Making all allowance for occasional errors, I give my confidence to the great Table of De Verneuil and D'Archiac; for it is mainly compiled from the labours of Phillips, Murchison, Münster, Von Meyer, Goldfuss, and other highly esteemed observers. This Table proves the connexion between the Carboniferous, Devonian, and Silurian systems to have been well-marked, and that such changes of sediment as were required for the sustenance of the new inhabitants did not always forbid the survival of the old life. M. De Verneuil's Table proves that the Carboniferous system of Europe is connected with the Lower Silurian by 4 forms, with Upper Silurian by 13, with Lower Devonian by 53, with Upper Devonian by 6,—being in all 76, a number which future research will augment.

By a Table which I have constructed, it is shown that 204 species out of 1123 occupy, each in different countries, distinct stages and even systems. If these fossils have been correctly designated, as I believe, we are then in the presence of a purpose of unimaginable duration and extent, embracing nearly three-fourths of the sedimentary rocks of the earth. By entering and pervading the successive horizons from the Lingula-flags to the Carboniferous limestone, these recurrent fossils teach us how intimate, amid endless lithological mutation, are the mutual affinities of the palæozoic periods, and that the organic life of those times was intended to manifest the same benevolent infinity of resource which now lavishes a beauteous and boundless variety upon our earth.

In studying the European Devonian Recurrents at long intervals, or from system to system, we find that the nearest stages are the most closely allied by their faunæ. Tracing now the life-relations of the different stages, we perceive that the Upper Silurian stage is connected with the Lower Devonian by 72 fossils exclusively their own, while the Lower Silurian is only united to the Lower Devonian stage by 19 fossils, only found in those stages. Nine fossils form a somewhat feeble bond of union between Upper Silurian and Upper Devonian; but Lower Devonian sends 49 fossils into Carboniferous strata. The most remote stages are the least connected. The Lower Silurian and Upper Devonian have only one common form, the *Favosites fibrosa*, an inhabitant also of the Onondaga Limestone (Devonian) of New York. These facts remind us of the gradual weedings observed in the fossils of the *Tertiary* rocks as we proceed from below upwards.

With respect to individual orders and genera. The recurrent *Zoophyta* of Europe are very numerous, being 35 out of 62, contrary to expectation from their habits in New York, from the simplicity of their essential parts, and from their being sedentary. *Syringopora ramulosa* is Silurian at Limbourg, and Carboniferous at Visé, Moscow, and Valdai; *Gorgonia ripisteria* is found in each of the systems—Silurian, Devonian, and Carboniferous. Only 8 Devonian *Bryozoa* are recurrent; but the range of these is extensive. *Fenestella antiqua* occupies three stages. So restricted in New York is the range of the Silurian Crinoids, that we may be surprised to find 12 here out of 60 in various horizons. One species of the genus *Rhodocrinites* is met with in all the three systems, but not in Permian. Of the 61 *Brachiopoda* recurrent and Devonian in M. De Verneuil's Table, the species of only 3 genera are in any considerable number,—namely, 11 *Orthides* recurrent out of 48, 18 *Spiriferi* out of 57, and 21 *Terebratulæ* out of 54. Only one European *Orthis* (an early genus) reaches the Carboniferous period; but the other two genera do so plentifully from very early times. The *Leptæna membranacea*—of New York, South Africa (Sharpe), and Europe—frequents the three middle systems in Europe, together with *Chonetes sarcinulata*. Only one *Bellerophon* (*B. elegans*, Lower Devonian) attains to the Coal-measures. Of the 98 European *Goniatites*, only 4 reappear in newer strata, 3 of these passing from Lower Devonian into Carboniferous. Barrande is inclined to believe that he has met with this fossil in the Upper Silurian of Bohemia. *Orthocerata* are mostly typical, only 12 out of 56 being recurrent; but 6 enter the Carboniferous system. Nine out of 39 species of European Trilobites (7 genera), chiefly of Devonian origin, have vertical range; two reach the Carboniferous rocks, where the family entirely dies out. The following is a List of the species of the Silurian and Devonian fauna which pass into the Carboniferous system:—

The species occurring in the *Lower Silurian Stage* in Europe, and found in Carboniferous strata, are—

Chonetes sarcinulata.
Pleurotomaria Defrancii.
Pleurotomaria undulata.
Orthoceras cinctum.—(4.)

Those of the *Upper Silurian Stage* are—

Gorgonia ripisteria.
Rhodocrinites verus.
Leptæna membranacea.
—— analoga.
Spirifer crispus.
—— octoplicatus.
Inoceramus vetustus.
Sanguinolaria angustata.
—— sulcata.
Turbo bicarinatus.
Trochus Avanii.
Orthoceras Ibex.
—— bullatum.
Calymene concinna.—(14.)

From the *Lower Devonian*—

Cyathophyllum flexuosum.
—— quadrigeminum.
Ceriopora verrucosa?
Syringopora ramulosa.
—— reticulata.
Actinocrinites lævis.
—— triacontadactylus.
Melocrinites lævis.
—— hieroglyphicus.
Platycrinites depressus.
—— pentangularis.
—— tuberculatus.
Pentremites ovalis.
Atrypa cuboides.
Orthis umbraculum.
Productus scabriculus.
Spirifer cuspidatus.
—— distans.
—— glaber.
—— oblatus.
—— resupinatus.
—— rotundatus.
—— subconicus.
Terebratula acuminata.
—— elongata.
—— hastata.
—— Mantiæ.
—— pugnus.
Terebratula reniformis.
—— rhomboidea.
Pterinea elegans.
Pecten linteatus.
—— plicatus.
—— transversus.
Cardium aliforme.
—— hybernicum.
Euomphalus Labadyii.
—— Schnurii.
—— serpula.
Buccinum acutum.
—— imbricatum.
Loxonema rugifera.
Murchisonia angulata.
—— spinosa.
—— tæniata.
Pleurotomaria delphinuloides.
—— limbata.
—— monilifera.
Bellerophon elegans.
Cyrtoceratites armatus.
Goniatites expansus.
—— serpentinus.
—— sphæricus.
—— cylindraceus.
—— giganteus.—(55.)

From *Upper Devonian* (besides recurrents from below and already enumerated)—

Fenestella laxa.
Leptæna analoga.
Productus laxispinus.
Spirifer lineatus.
Terebratula pleurodon.
Loxonema tumida.—(6.)

The following points are worth recording:—The proportion of Devonian recurrents in Europe generally, according to the Table of De Verneuil and D'Archiac, is $\frac{2}{11}$ths of the whole, which is considerably greater than the $\frac{2}{13}$ths which we found to rule in New York. Thirty-four out of 207 European recurrents (Devonian) are met with in New York (and 4 more in Ohio and Tennessee), with, in many cases, considerable vertical range. One-sixth of these Devonian recurrents being thus common to both continents indicates a strong affinity between their respective palæozoic basins; and the fact obtains additional force when we remember how very dissimilar palæozoic provinces, far nearer geographically, are in Europe. In both hemispheres all the orders and most of the genera have their representative recurrents; and they are principally *Brachiopoda, Gasteropoda, Lamellibranchiata*, and *Zoophyta*.

§ 4. *On the Grouping of Fossils, and their Order of Precedence.*—The Invertebrate species of the palæozoic strata of New York, and of all other examined regions, were purposely grouped by the Creator in societies on their respective horizons, and were adapted to live among a complicated balance of agencies, favourable and unfavourable. There was a predetermined harmony in the mutual relations of the new beings, and a predetermined amount and kind of sustenance provided, such sustenance being derived ultimately from the sediments and the water in which they existed. Different assemblages of forms prevailed in each sediment, according to its mineral constitution; so that certain New York group-sections, far removed from each other vertically, are yet peopled by the same genera at least, and often by the same species. This is exemplified in a striking manner by the argillo-calcareous strata of the Trenton and Niagara sections, although not even in the same stages of the system. Generically, both these sets of beds are tenanted conspicuously alike by *Annelida, Echinodermata, Zoophyta*, &c. The Devonian strata, Hamilton and Chemung, principally argillo-arenaceous, give similar testimony. The races here are the same to a singular extent, and even specifically, although separated by three horizons. The more purely arenaceous sections of this Silurian basin, however, do not agree so closely in their population, both from the ever-changing nature of their lithological characters, and from the very various periods of geological time, and other circumstances under which they were laid down. We see all this in the Calciferous Sandstone, Medina Sandstone, and Onondaga-Salt group of New York. We perceive, then, that the successive introduction of animal life was not regulated by simplicity or by complexity of structure; for both have been contemporaneous from the beginning. Mutual suitability, and, in a great degree, the dependence of the higher on the lower organisms (the former consuming the latter as food), was a governing and universal law. The earliest animals are the *Brachiopoda, Annelida,* and Trilobites, in distant localities, usually of the same genus, seldom of the same species. They exercised their instincts on rocky or on muddy bottoms, and amid tangled masses of sea-weed. In this last position we may find infinite numbers of minute Trilobites (Forchhammer), an order of high rank in the great series of Invertebrate development. The existence of a compound eye in the Trilobites of the Potsdam Sandstone (Upper Mississipi, D. D. Owen) is a striking circumstance.

Of the exact nature of all these operations, we shall probably never obtain more than a general idea, although framed on the principles ruling at the present day, because elements, vital and physical, existed, of the kind and amount of which we are entirely ignorant. Thus, not to speak of coast-lines and other oceanic conditions, the *Tunicata* might have been numerous and influential, as well as the Rhizopodous tribe lately discovered in great abundance by Ehrenberg in the very earliest Silurian strata near St. Petersburg. Some parts of the animal kingdom may have been lost for want of a speedy removal within the embrace of a preserving material, from the many destructive agencies which labour unremittingly in all parts of the ocean, the simplest structures disappearing soonest. A glance at the General Table of the Silurian Fossils of New York, will at once convey more information as to the animals composing these usually internecine societies than could be spread over many pages. I shall now select a few leading particulars regarding the successive appearance of the Silurian fossils of New York, reviewing generally the newly placed fossils as they originate in the series of strata.

We may here remark that nearly all the genera of New York Siluria were introduced in its middle and lower stages, a diminution of creative energy having prevailed in the upper stage. The Devonian of New York is marked by a plentiful and interesting development of new forms.

1. *Potsdam Sandstone.*—Plants or plant-like fossils make their appearance first. In Wales but few have been collected and described. In New York, however, they are apparently much more numerous, and occupy nearly every arenaceous group upwards into the Clinton Sandy beds, where they culminate. Up to the present day, the fucoid markings have not been sufficiently studied, although full of important information. They are all marine, and occur chiefly in the sandstones which fringed the ancient coasts. The very interesting Brachiopod, the *Lingula,* appears in Potsdam sandstone; and in certain spots individuals are multitudinous. Abounding most, like many others of their order, in Trenton Limestone, they are found in Utica Slate and the Hudson-River rocks, and are then absent upwards through many epochal centres, to reappear in Devonian strata. This seems to be a law; for the same takes place in Wales and other countries. Co-tenants with the *Lingulæ* are two genera of Trilobites—one lately discovered in the north part of the State of

New York by an American professor, and another species by Professor Desor of Neuchatel. The other genus, found and described by Dale Owen, is from the Upper Mississipi and its tributary the River Lacroix. Some genera, as *Phacops* and *Calymene* are continued through the Silurian and Devonian systems, and without change of form in some. More than half of the Trilobites of New York and Wales are of Lower Silurian origin; and twelve genera never leave it. A quarter of the whole meet in Trenton Limestone, where they attain their maximum, as in upper Bala, its Welsh representative; and then they gradually decrease in numbers upwards and downwards, not one appearing in the Calciferous sandstone. The genera *Olenus* and *Beyrichia*, which in Europe are among the very first animals visible, in New York delay their appearance until the Mid-silurian stage is partly deposited. The singular Crustacean, *Eurypterus remipes*, appears in both countries nearly at the same epoch. In Wales the *Crustacea* occupy every sedimentary group, and by 210 appearances (Salter); in New York they show themselves in 10 sections, by 68 appearances. In this last area, only 9 species appear posterior to the deposition of the Niagara strata (including the Devonian), which is a decrement as rapid as that observed by Murchison in Russia*. The case is much the same in Wales. In the "Eastern Region" of Phillips, however (embracing Usk, Tortworth, Mayhill, Woolhope, &c.), the Upper Silurian Trilobites are 19, to 8 Lower Silurian,—a condition of things very different from that seen in other parts of Wales. The two basins of which we always speak possess 18 genera in common; but New York has 5, and Wales 21, which are distinct, and possibly peculiar. In both hemispheres, *Acidaspis*, *Agnostus*, *Bronteus*, *Ogygia*, and *Proetus* are non-recurrent,—a remarkable coincidence. In the number of species neither basin, as yet, approaches that of Bohemia (230 species of Trilobites), and Scandinavia (350 species). The Irish Trilobites assimilate to those of New York in their common genera, *Isotelus* and *Asaphus*. Few genera originate in Upper Silurian,—some of the successive appearances there being recurrent forms. The Welsh basin is twice as prolific as the American; but the animals appear in both at the same period—Llandeilo or Trenton (which last includes the Chazy and Birdseye limestones). Precedence does not seem to depend on physiological grounds. The genera rich in species in the one country are so in the other, and *vice versâ*, but with exceptions.

2. *Calciferous Sandstone.*—In this set of strata no members of the Potsdam fauna exist. Six *Gasteropoda*, with the beautiful *Ophileta*, three *Orthoceratites*, a *Bellerophon*, and a *Euomphalus* are substituted. Individuals are plentiful, but species are rather few. This applies to the genus *Euomphalus*, which is first met with in this rock, which is equably spread over Welsh Siluria, where its species commence their existence almost on the same horizon with their American congeners. The species of *Orthoceratites* alluded to live and die here; but the genus survives through 9 sections in New York, as carnivo-

* Geol. of Russia, vol. ii. p. xxii.

rous animals of high organization and possessed of great strength and activity. Species are most in number in Trenton Limestone, but are elsewhere common, and present themselves in three groups of Middle Devonian. In Wales they are met with on the same horizons, but culminate in far newer strata—those of the Lower Ludlow. The total number in Wales is 35, inhabiting 9 groups. In New York their number is 40, met with in 9 groups also—another curious coincidence. In Wales they never attain the vast size of those in the Black-River and Niagara sections. In the latter I have seen them 6 feet long.

3. *Chazy or Black-River Limestone.*—An abundant and varied fauna enlivens this section. Here we have the first Zoophytes. This order pervades 11 Silurian and 6 Devonian sections in New York. Numerous in Trenton and Onondaga Limestones and in the Hamilton series, they are in still greater force in the Niagara rocks, just as the Welsh *Zoophyta* are in the Wenlock rocks on the same horizon. Three species of *Crinoidea* are seen in the Chazy group; and in all probability more will be detected. None are met with in the Birdseye Limestone; but there are 11 in the Trenton. In the Niagara rocks 31 species appear, and of great beauty. From this last epoch they diminish in numbers rapidly. James Hall, however, expects soon to add largely to both these orders from the Upper Silurian and Devonian of this basin. They are very numerous in the English and Rhenish horizons of the same date. The three great genera of *Brachiopoda*, namely *Leptæna*, *Orthis*, and *Atrypa*, with the lesser one, *Orbicula*, make their first appearance in Chazy Limestone, the species not being numerous. Several of the 17 genera of Silurian *Brachiopoda* of New York (*Megalomus*, *Meganteris*, *Merista*, *Leptocelia*, and *Waldheimia*) run very short courses; but the others exhibit great tenacity of life. In Wales 6 out of 19 genera are short-lived.

The genus *Leptæna* of New York has its greatest number of species in Trenton Limestone, and diminishes slowly from that point in the palæozoic series both upwards and downwards. All this is true also of the Welsh *Leptæna*. This genus is numerous and varied in the Middle Devonian of New York. They inhabit 7 sections, —9 species being in the Hamilton rocks, and 10 in the Chemung.

The 50 *Orthides* of New York Siluria culminate in the Trenton; there is only one in the Chazy Limestone. In the course of 9 sections this genus mounts up into Upper Pentamerus Limestone, the newest stratum of this system. As to the Devonian system, it is most abundant in the Hamilton rocks, the species being six there.

The 73 *Atrypæ* of New York occupy 13 sedimentary groups; but they are most plentiful in the Trenton, Clinton, and Niagara and the central groups generally. The succeeding species are either new creations or derivatives from earlier life-provinces. They enter the Carboniferous system. The Chazy Limestone has only one Lamellibranchiate genus, the *Ambonychia*. Five of its 7 Gasteropodous genera have short lives. The genus *Murchisonia* originates here, and, taking the whole of the Silurian system in New York, gives us

23 species—16 being Lower Silurian, and 9 in the Trenton Limestone alone. Wales has 11 species, and of similar position and relations. This genus arises in the Caradoc or Bala rocks in Wales, and is of equal force in all the three stages.

4. *Birdseye Limestone.*—Life exhibits very few forms here. The most interesting is the American genus *Bucania*, a Gasteropod allied to *Bellerophon*. It is present in all the three Silurian stages, in 12 species; but it is far most numerous in the lowest. The same may be said of the genus *Modiolopsis*, in 24 species (Dimyarian). The bivalve Crustacean, *Cytherina* (?) as formerly called, is first seen here. It has 5 species, each in a separate group, 3 being Upper Silurian.

5. *Trenton Limestone.*—The *Annelida* of New York commence their existence here, excepting one, *Scolithus linearis*. They will before long be proved to be more abundant than has been hitherto suspected. Although few in this epoch, the species are known in 8 group-sections, which sections are in contact only in three instances. This order prevails more largely in Wales, where we find it in all the rock-groups which range from the Lower Bala to the Ludlow inclusive. The genus *Spirifer* first shows itself in the Trenton section by two malformed species, just as in Wales (Upper Bala). It is spread thinly over the Silurian system generally, and has two places of greatest development, the Niagara and Delthyris Shaly limestones. In the Devonian strata it multiplies suddenly into 53 species,—11 being in Corniferous Limestone, 19 in Hamilton, and 14 in Chemung rocks. The species of *Spirifer* found principally in Devonshire are, according to Phillips, 27 in number ('Manual,' p. 146). *Avicula*, a Monomyarian genus, arises in the Trenton Limestone, and spreads over 10 sections, in 22 species, principally in Upper Silurian. There are 31 species in Middle Devonian of New York, with 14 in the Hamilton Rocks. Life is powerful in this genus; for from the Trenton Limestone it runs up to Chemung at the base of Old Red Sandstone. In this section also we meet with *Tellinomya*, a genus of short duration in Silurian strata. Nine *Dimyaria* and *Gasteropoda* come into view here; but they do not call for any observation. The first Pteropod, *Conularia*, is seen in the Trenton Limestone. The Canadian, and perhaps the New York, *Conularia* is in form and decoration more perfect than any English specimen which I have met with. This genus only appears in the Silurian strata of New York twice, and once in the Hamilton group of Mid-devonian. It has only one form (*C. Sowerbyi*) in the Silurian of Wales.

6. *Utica Slate.*—Although this section is of great thickness and extends over very large surfaces, it originates few fossils. There seems to be here an arrest of life, which is the more remarkable from its being chiefly composed of the same argillaceous shale which is so plentiful in the highly fossiliferous rock preceding it.

7. *Hudson-River Rocks.*—In these strata fossil life multiplies considerably, especially as to the *Dimyaria* (18) and *Graptolites* (7, new). This might be expected from the nature of the matrix which this section affords.

8. *Medina Sandstone.*—This set of strata gives us only one new genus (*Arthrophycus*), and but 18 species of any kind of life. There is, however, here and in the Clinton a sudden influx of marine plants in vast masses, as if, at the commencement of a new phase of organic life in the Middle Silurian stage, it was intended to provide a rich supply of new aliment.

9. *ClintonRocks.*—It is here that the characteristic Brachiopods *Pentamerus*, *Chonetes*, and *Strophodonta*, first occur, together with a single species of the genus *Posidonia*, the Gasteropods *Cyclonema* and *Platyostoma*, and one or two Cephalopods ; but, beyond noticing the great importance of the *Pentameri* in palæozoic chronology, no further remark needs to be made on the fossils of these rocks. As very few new forms are developed, as far as yet known, in the Niagara and succeeding sections, this part of our subject may now be closed, by observing that the statements just made have exhibited a determinate plan in the order of precedence in ancient life,—determinate, because we see, from concurrent evidence, that the same method and order has been pursued in Ireland, Wales, and on the continent of Europe, as in the State of New York.

§ 5. *Increment and Decrement.*—Palæozoic genera and species undergo "increment" and "decrement" (numerical increase and decrease) in passing through the two systems, Silurian and Devonian ; or it may be that their numbers remain stationary throughout the whole range of epochs. This law becomes very interesting, by pointing out a remarkable agreement, in this respect, which obtains in the two distant, and not altogether similar regions, of New York and Wales. Out of 24 orders and genera, thus comprising nearly the total faunæ of both countries, there are only five instances of disagreement, chiefly in the order of Gasteropods, namely in the genera *Murchisonia*, *Pleurotomaria*, *Bellerophon*, and *Orthoceras*; and I am not aware that the omission of any of the poorer genera at all disturbs this law of conformity, which, we must now add, extends to Russia in its Trilobites and *Orthides*, in its *Halysites catenulatus*, and probably in more forms still, judging from many resemblances in other points.

In both New York and Wales, increment upwards and increment downwards take place in the same 8 important groups of fossils (16 altogether), while in 3 others the number of species remains about the same throughout the series of Silurian rocks. Or the same genera in the two countries now under comparison may decrease upwards and downwards from the same culminating point. These facts admit of an important application, and show, as De Verneuil has inferred on a kindred subject, that the law which presided over the numbers of animals is universal, and not dependent on local occurences of any kind. Most of these facts are well exhibited in Table XVI.

§ 6. *Duration of Invertebrate Life.*—The fauna of this or of any other period was intended and adapted to endure for an appointed time, as consisting of finite beings. As one of the methods of fulfilling this intention, great mortality has prevailed at the end of each epoch, preceded by a gradual diminution in the quantity and variety of life towards its close,—multiplying nevertheless, upon the whole, in the long ascent of successive deposits. Since a great part of the palæozoic creation was carnivorous, Trilobites even devouring one another, in primordial ages, for want of other sustenance (Barrande), and since all were liable to sudden external changes, violent death was the ordinary or common lot, but, of course, together with the slower extinction by disease, &c. The disappearance of feeding-grounds, occurring more or less at the end of an epoch, although fatal, was not always abruptly so; for we frequently find, in the earlier strata of a

TABLE XVI.—*Increment and Decrement.*

| Orders and Genera. | Increment Upwards. | | Decrement Upwards. | | Stationary, or nearly so. | |
|---|---|---|---|---|---|---|
| | Wales and Siluria. | New York. | Wales and Siluria. | New York. | Wales and Siluria. | New York. |
| Plantæ | ... | ... | ... | ... | * | * |
| Bryozoa | * | * ? | ... | ... | ... | ... |
| Zoophyta | * | * | ... | ... | ... | ... |
| Echinodermata | * | * | ... | ... | ... | ... |
| Atrypa | * | * | ... | ... | ... | ... |
| Rhynchonella | * | * | ... | ... | ... | ... |
| Spirifer | * | * | ... | ... | ... | ... |
| Avicula | * | * | ... | ... | ... | ... |
| Euomphalus | * | * | ... | ... | ... | ... |
| Ambonychia | ... | ... | ... | ... | * | * |
| Cleidophorus | ... | ... | ... | ... | * | * |
| Trilobites | ... | ... | * | * | ... | ... |
| Leptæna | ... | ... | * | * | ... | ... |
| Lingula | ... | ... | * | * | ... | ... |
| Orthis | ... | ... | * | * | ... | ... |
| Pentamerus | ... | ... | * | * | ... | ... |
| Modiolopsis | ... | ... | * | * | ... | ... |
| Orthonota | ... | ... | * | * | ... | ... |
| Nucula | ... | ... | * | * | ... | ... |
| Gasteropoda | * | ... | ... | * | ... | ... |
| Murchisonia | ... | ... | ... | * | * | ... |
| Pleurotomaria | * ? | ... | ... | * | ... | ... |
| Bellerophon | ... | ... | ... | * | * ? | ... |
| Orthoceras | * | ... | ... | * | ... | ... |

new series, several (or many) of the species belonging to the period just past, the individuals having as it were struggled for existence.

Vital power, or viability, differs greatly as we look upon it in individuals, species, or genera. Of the length of life enjoyed by the first of these in palæozoic times we know nothing, and not much respecting those of the present day; but possibly that of the latter may be learnt more or less exactly from the earlier or later maturity of the animal, as suggested to me by Mr. T. Davidson. The comparative duration of a species is not so difficult to ascertain; for in the majority of cases it is confined to a single phase or era. Where not thus restricted, but recurrent, the same species may be found in the Silurian, Devonian, and Carboniferous systems; and this involves a duration inconceivably protracted. The shortness of specific life is more apparent than real, because all the epochal subdivisions occupied long intervals of time; and thickness, therefore, all other things remaining the same, becomes a measure of longevity in species. Where the thickness was great, and where the chemical and mineral nature of the sediment and the sea was favourable (the latter having a suitable depth and temperature), there was great length of species-life, and, as a consequence, great geographic diffusion. We see this very distinctly in the Upper Silurian of New York, Wales, and Bohemia. Palæozoic genera were not often long-lived. Of the 192 found in the Silurian rocks of New York, 124 are never seen out of their original rock-group; 23 enter only into one newer group; 14 into two; 7 into three; a Trilobite (*Calymene*) into 5 newer; an *Atrypa* (*A. reticularis*) into 9 groups; with a few other genera scattered. These remarks apply to the fossil organisms of Wales. Out of 228 genera occurring there, 149 never leave their first position; 44 appear twice, 24 three times, 9 four times, and 2 in five epochs, according to the General Table in the second edition of Sir R. Murchison's 'Siluria.' It is not possible to compare the viability of the faunæ of these two basins very closely, because they are not exactly the same; but where they are so, we are pleased to see the poor and the prolific genera to be the same in both,—indicating a degree of mutual organic representation in these two widely separated basins.

§ 7. *Epochal and Geographical Diffusion of Species.*—The following reflections present themselves on a survey of processes so ancient and prolonged as those which laid down the palæozoic strata of New York. It is only on vast continents such as America, that the complete unbroken whole of a grand geological conception like the central palæozoic basin of the United States can be seen and grasped. In smaller spaces, as in islands, the idea becomes fragmentary, its beautiful relations are submerged, and much of the lesson is lost. These conceptions are not like those of man, cogitated, modified, laboured at for an hour, a year, or a life-time. The omnipotent Creator requires no period of hesitation and contrivance; all is execution through inconceivable extensions of time. His operations are ubiquitous, with all their parts coordinated. A great formula is being worked out by a predetermined series of processes, both simple and complicated, in all parts of the globe. New existences have peopled the successive groups of strata, partly by direct creation, and partly by migrations, the latter occasioned and facilitated by never-ceasing agencies, plutonian and neptunian. Fossils may be contemporaneous in geological age without being contemporaneous in point of time as time is commonly understood. Geological age is in great measure determined by the evidence of fossils. Now the presence of certain races (subsequently fossil) depends on inconstant conditions, mineral, meteorological, and oceanic, on the accidents of plutonic action, and on the varying thicknesses of deposits (so small in Scandinavia, and so great in Britain, &c.). All this produces a set of changes which are local and limited, so that the universal scheme is not everywhere worked up to the same point at the same instant. Here preparations were being made by vertical oscillations for Silurian deposits, there for Devonian, the older beds having been already laid down. Suppose for a moment, that the crust of our planet possesses 50 groups of sedimentary strata, 50 epochal horizons in fact; none of these in their several localities were *necessarily* formed at the same time; so that absolute isochronism in groups cannot be common. Sir Henry De la Beche* hints at this. Barrande † in like manner admits, not an absolute synchronism of faunæ, but only relative contemporaneousness in the flux of time—a proximity of existence. All faunæ and floræ were individually perfect from the very earliest epochs, and many were highly organized ‡. We see this in the complex eye of the Trilobite found in the Potsdam Sandstone of the Upper Mississipi, in the *Hymenocaris* of the Welsh Lingula-flags, and in other less striking cases.

During the palæozoic and other geological periods, there were two kinds of provinces, circles, or centres of life:—the "geographic," which occupied the same horizon in scattered centres, each having its own population more or less peculiar; and the "epochal" or "geological," which, with the advance of science, are every day becoming more numerous in many parts of the world. They exist on their own distinct horizons, and are confined each to a single condition of things, denominated an epoch or a formation. The same epochal province may contain many geographic circles, or possibly only one. Both the geographic and epochal circles will soon become of high importance, as the means of reconstructing or restoring to the mind's eye, though imperfectly, the earth's surface, its configuration and contours, at the different epochs. The members of these faunæ, aided by sun-cracks, ripple-marks, animal-tracks, and such-like, will be used as guides from land to land, in the same way as Plants were used by the late Edward Forbes, and the Molluscs of the present day by M'Andrew, connecting and disconnecting large and interesting portions of the earth in historic geology. As regards the geographic province, I am not sufficiently instructed in Agassiz's hypothesis of the simultaneous (or nearly simultaneous) planting of many such over the surface of the earth during any given epoch, to give any opinion about it. At present, I am content to say that, the great laws of animal distribution being the same then as now, zoological provinces were everywhere formed, but each with a far wider diffusion than at this day; for, from their great size, from the rarity of coast-lines, change of place was made easy to their inhabitants in search of food and shelter. Near to the means of subsistence they would naturally crowd. Examples of geographic provinces in the palæozoic series abound, and are very striking. Thus, in Russia, De Verneuil found 205 species exclu-

* Mem. Geol. Surv. vol. i. p. 103.
† Syst. Sil. Bohême, p. 72 *c.*
‡ Murchison, De Verneuil, and Keyserling, Russia, vol. ii. p. xxx.

sively Russian out of 392, or 48 *per cent.** ; James Hall finds 369 new species out of a total of 900, or about 40 *per cent.*; while, of Sir C. Lyell's small collection of American fossils, five-sixths are new to Europe, according to the late Daniel Sharpe. In the same way General Portlock, in his Summary of the Tyrone and Fermanagh Fossils, finds 105 forms (principally *Crustacea*, *Cephalopoda*, and *Dimyaria*), out of 188, peculiar to Ireland, or 54 *per cent.*†. Each of these countries therefore presents a geographic province. Professor J. Phillips calculates that, out of 430 of the fossils of the *adjacent* districts of Woolhope and Abberley, only 96 are common to them both, giving the remarkably large per-centage of 76 to the restricted fossils‡. Lockport, in the State of New York, and Drummond Island in Lake Huron, both on the same geologic horizon, differ widely in their extinct faunæ; and it is a most remarkable fact, that the Scandinavian and Bohemian basins, about 800 miles apart, have but 1 *per cent.* of their very numerous Trilobites in common, and only 5 *per cent.* on their whole faunæ. We must remember that there are a multitude of causes which make the species of the same epoch vary in its different localities,—such as depth or dilution of sea-water, the contents and rates of currents, and other agencies already alluded to. In the Lake of Stennis in the Orkney Islands, however, we have a beautiful instance of the facility with which certain marine genera (*Cardiaceæ* and *Mytili*) have continued to live on amid their new associates, the *Limnææ* and *Neritinæ* of fresh waters, while the others perished. This lake has been gradually converted from a salt-water loch into a freshwater or marshy tract §.

The second kind of life-centre, the epochal, occurs in vertical and almost independent succession. Each of the palæozoic sections of New York and Wales has its own typical or epochal fossils, besides those which are recurrent. The genera often survive, species more rarely. A new epoch is usually produced by a change in depth, the result of insensible oscillations—a movement of depression or elevation, which is almost always going on||, and which necessarily occasions new currents, new sediments, and new animal occupants. It is very interesting to notice the frequent commixture of fossils about the outer or terminal layers of two adjacent sections or epochs, and to witness their gradual replacement in the deeper situations by a new assemblage of life. Geologists now agree¶ that this proves that new epochal centres of life were introduced quietly and with little disturbance. D'Orbigny has a strong opinion to the contrary **; but facts are clearly against him. These provinces, universal and indisputable, are particularly well defined in New York. They owe their origin to an agency very different from that which gives rise to geographic centres; and so occult is that

* Geol. of Russia, vol. ii. p. 396. † Portlock, Geol. Londonderry, p. 476.
‡ Pal. Foss. Dev. p. 178. § Murchison, Geol. of Russia, vol. i. p. 302.
|| Dana, Address Amer. Assoc. 1855, p. 315.
¶ Barrande, Syst. Sil. Bohême, p. 72 *d*; Hall, &c.
** Cours Paléont. vol. i. p. 93, and vol. ii. p. 252.

agency, that Agassiz and Barrande are constrained to attribute the presence of whole communities of new living beings in sedimentary rocks to direct creation. In the actual state of our knowledge, there seems no other method of accounting for the existence of peculiar, well-adjusted, and variously-peopled life-provinces through a series of distinct horizons, but to ascribe the fact to creation by divine power as a regular, not a casual, transaction, and as a determinate part of a suite of combined phenomena. It took place, in all probability, by epochs or periods; and it is not likely, judging from our own times, that it occurred at different parts of the same period. This creative power (solely an attribute of Deity, and incommunicable), now generally admitted, may have been exerted through secondary means; but the really efficient of these, being peculiar and profound, working too in some inappreciable nascent form, will for ever elude the most eager questionings of man. It should not be forgotten that *animal conservation* (the sustaining of life) is but a *continuata creatio*, or, to use the words of Charnock, "conservation is but one continued act with creation, following on from instant to duration, or as a line from its mathematical point." The growth of organized forms is just as wonderful, and to me as inexplicable, as creation itself. Considerations like these may incline us the more readily to admit of successive direct creations, in carrying out a process immeasurably lengthened in duration, and co-existent with the earth. That migration existed in palæozoic times is almost certain, and the means are obvious; but it did not occur to the extent which might have been expected. Had it been very great, centres of diffusion (or geographic provinces) would have been greatly obscured, if not obliterated; this, however, was not the case, even in contiguous parts of the same basin.

§ 8. *Recurrence.*—The recurrence, or reappearance in new epochs, of any given organic form, must be either by creative power, migration, or translation—the last being a passive act,—and either as germs or eggs, or in the dead state. Sir C. Lyell denies the repetition of species by the first-named of these methods, in the following words*:—"There are no facts leading to the opinion that species which have once died out have ever been reproduced." He further observes†, "That an intermixture and blending of organic remains of different ages have taken place in former times is unquestionable, though the occurrence appears to be very local and exceptional. It is, however, a class of accidents more likely than almost any other to lead to serious anachronisms in geological chronology." James Hall declares ‡ that "the Creator never repeats the same form in successive creations: the various animals have performed their part in the economy of nature, lived their time, and perished." I cannot, however, readily attribute to migration or translation the hundreds of acts of recurrence we meet with in all the examined portions of the world, amid the innumerable obstacles to such a transition, which sometimes overleaps many and great epochs. And it is not to be

* Principles, p. 191. † Principles, p. 775.

‡ Palæont. vol. i. p. xxiii.

forgotten, that in the comparatively easy wanderings on the same epochal horizon migration was probably neither frequent nor extensive. So at least we are taught by Troost as to the State of Tennessee, by our President, Professor Phillips, in England, and by Barrande in Bohemia. "For," says Barrande*, "we should expect that on a surface so limited as that of Bohemia (60 by 15 miles in its greatest dimensions) the fauna would be distributed uniformly; but it is not so. This basin presents, on a small scale, the same absences or inequalities of distribution which we remark on a large, over the whole globe, whether at the present day or in palæontological times. The Trilobites, in particular, here have their principal residences, occasionally only a few square-yards in extent; and thus they seem few until these centres of diffusion are discovered." But migration is a true agency. The escape of a single individual into an upper bed may people with its descendants many epochs and districts. Angelin, Pictet, D'Orbigny, and Agassiz coincide in opinion with the great authorities just named, and affirm that species did not reside in more than one palæozoic epoch or platform, or as mere exceptions which, according to Agassiz, become more and more rare with the progress of palæontological knowledge. Angelin absolutely meets with no specific form which passes from one to another of his seven local stages or regions. In the first volume of his 'Contributions to the Natural History of the United States,' p. 104, Agassiz broadly announces the axiom, "that facts exhibit the simultaneous creation and simultaneous destruction of entire faunæ" in the palæozoic ages,—and this, in minor periods or subdivisions (p. 96), accompanied by a coincidence between these changes in the organic world and the great physical changes of the earth. But it appears to other observers, fully as competent as the honoured men just-named, that recurrency or vertical range is a fact which occurs in a large number of fossils in almost every horizon, the very number (scrupulously ascertained) being far too great to allow of the plea of constantly mistaken identity. The voluminous and highly esteemed writings of James Hall are full of instances of recurrence, established by himself, and for the moment by him forgotten. We see from Table XII., that they are 280 in number. Daniel Sharpe, one of our most acute palæontologists, witnesses to the same effect. Prof. H. D. Rogers, of Glasgow, gives similar testimony for Pennsylvania; and M. De Verneuil states authoritatively that the same fossil species are scattered through the palæozoic systems of America at different levels. This is in the *résumé* of his Parallel between North America and Europe†. His remarks on the palæontology of Russia are completely in the same sense‡. Vertical range in fossil species prevails to so great an amount in Wales and the adjacent counties (Murchison and Morris), that it unites into one epoch strata lately considered separate; and it is even more remarkable in the eastern districts so well described by our present President. The experience of General Portlock in Ireland tends in the same direction. In Bar-

* Syst. Sil. Bohême, p. 290. † Bull. Soc. Géol. France, 2 sér. vol. iv.
‡ Geol. Trans. n. s. vol. vi. p. 334.

rande's able brochure entitled 'Parallèle entre les Dépôts Siluriens de Bohème et de Scandinavie,' 1856, it is stated that he finds few or no common species among the six stages of Bohemia; but if we refer to his great work on the Trilobites of that country, we shall find the following facts contradictory of this statement (see p. 76 for particulars). While the relations of his stages E and F (Upper Silurian) are in no degree intimate, they still have the large number of 14 Brachiopods and 8 Trilobites in common. Considering the general scantiness of life in stage G (Upper Silurian), a near connexion exists between stages F and G, because 22 fossils have found a common home in them both, 16 being Trilobites. Here, then, are 44 recurrents, of an unmistakeable character, in only three stages. Barrande * notices that 18 species of Trilobites inhabit two stages indifferently; and this takes place in both Upper and Lower Silurian; the same species, however, are confined to their own divisions. *Cheirurus Sternbergii* and *Phacops fecundus* are found in even four stages (about equivalent to groups, as usually constituted), and *Phacops Bronni* in three stages. The law of total extinction of life, therefore, at the end of each subordinate period, as propounded by M. Agassiz (none of whose words, however, should fall on careless ears), is not in harmony with what we observe in any of the sedimentary strata of the earth, except in Sweden, perhaps, according to Angelin. It is not confirmed, but negatived, by such careful examination as the great Silurian areas of New York and Wales have received. It is directly opposed to numerous facts gathered from the whole series of sedimentary rocks, palæozoic, mesozoic, and tertiary. A regulated and slow extinction of vegetation has been detected by Geinitz in the coal-measures of Saxony, with their five zones of vegetable life. They contain 156 species of plants. The first zone has only 1 species out of 23 common to it and the second and third; but between the second and third there are 33 species in common, with somewhat similar numbers common respectively to the other zones†. According to D'Orbigny ‡, all and each of the mesozoic and tertiary strata of France, excepting the New Red Sandstones, contain recurrent species,—the number, however, being usually small. But in Kelloway Rock there are 25 "recurrents" in 255 species; in Kimmeridge Clay, 16 in 183; in Miocene, 28 in 2726; and in Older Pliocene, 83 in 523. At p. 254 of the same work, D'Orbigny states that *Lima proboscidea* lives in three stages—the Inferior Oolite, Great Oolite, and Kelloway Rock,—and that certain 6 species inhabit the Kelloway Rock, Oxford Clay, and Coralline Rag of the Jurassic period. In examining the ten great stages of the English Oolite group, included between the Inferior Oolite and the Upper Calcareous Grit, Dr. Wright finds 21 species of *Echinodermata* which recur 31 times,—6 species making 3 appearances, and 2 appearing 4 times§. Prof. J. Morris informs me that several

* Syst. Sil. Bohême, pp. 282, 283.
† Pattison, 'The Earth and the Word,' p. 45.
‡ Cours Elém. Paléont. vol. ii. *passim.*
§ Rep. British Assoc., 1856, p. 400.

species of *Lamellibranchiata,* and of *Rhynchonella* and *Terebratula* among the *Brachiopoda,* range through the subdivisions of the Oolitic series. He also mentioned to me the circumstance, that the *Iguanodon* and *Lonchopteris* of the Wealden are found in the Lower Greensand. The assumed law of Agassiz is still further disproved by the graduated disappearance of Tertiary animal life, upon which Sir C. Lyell has based his beautiful classifications; and the same occurs in the vegetation of the Tertiaries, according to M. de la Harpe, as quoted in our President's Address for 1857. Mr. Davidson tells us that 3 species of tertiary *Brachiopoda* (*Terebratula caput-serpentis, Argyope cistellula,* and *Rhynchonella psittacea*) live at this day in the neighbouring coasts* ; and this is in accordance with the opinion of General Portlock, who sees in the records of Tertiary organic life only the evidence of an earlier epoch in the history of the animal world amongst which we live.

It must, however, be conceded, that at the end of every epoch or section the devastation among its inhabitants was very great, although seldom total. To speak now of the Silurian fossils of New York. Only one escapes upwards out of the Potsdam and Calciferous Sandstones,—both being strata of vast extent, in frequent contact or contiguity with others, and often themselves crowded with individuals. The same total destruction occurred in the corresponding stages of Bohemia. Of the 256 species in Trenton Limestone, 42 survive for a brief space, and then nearly all disappear for ever†. Of the 22 species in the Medina Sandstone, only two pass upwards; and out of 180 species of every order in the Niagara Section, all die but eleven at the close of the epoch. In Wales the fatality on the occurrence of similar changes of horizon, though very considerable, is not so great as in New York: in the Caradoc and Bala beds, as united in 'Siluria,' 2nd edition, 78 escape into newer strata, from an assemblage of 328 species; in Wenlock, 88 out of 177; but in Ludlow, out of 232, only ten reach some upper stratum, as the Passage Beds, or the Old Red Sandstone. These examples are all taken from sources of the highest authority, from the most recent writings of American geologists, as well as from those of Murchison, Portlock, M'Coy, Morris, Sharpe, and others.

While on the kindred subject of recurrency, a few words on the "colonies" of Barrande may not be amiss. In the centre of the micaceous schists (D 4) of the great stage D, in the Lower Silurian Division of Bohemia, lies a very slender and conformable band or wedge of Graptolite-schist, intercalated with trap. It is separated from the next stage upwards, E (Upper Silurian), by 4000 feet of schists and quartzites; but it contains precisely the same organic remains, and is of the same colour and mineral character. Barrande supposes that the materials of this thin band, with its 61 Upper Silurian fossils, were brought from the N.E., like those of the Upper Silurian rocks of Bohemia; the sediments of the Lower Division,

* Bullet. Soc. Géol. France, n. s. vol. xi. p. 177.
† See "Synoptical View," Table II, Q. J. G. S. vol. xiv. p. 420.

and their contents, coming from the S.W. He calls it therefore a "colony," adventitious and owing its existence to the argillaceous nature of a few deposits and the presence of a little lime. We have to remark that it is a colony without an ascertained source, without a mother-country, so far. No such phenomenon is known elsewhere. M. Barrande acknowledges that he knows of none. There is no instance in New York or Wales, as far as I am aware, of a single thin fossiliferous band, being developed after a long interval of time into a great stage. Species and genera, individually, may and do recur, but organic groups never—they are seen but once. There are mineral intrusions, or intercalations, such as Tully Limestone in the Hamilton Rocks of New York; but its fauna is not all peculiar, and it does not recur.

§ 9. *Comparison of the Palæozoic Basins of Wales and New York.*—Leaving these subjects, we may be allowed to state that the propriety of having studied the order in which fossils were introduced into their respective beds, their increment and decrement, and other topics which have engaged our attention, will be well seen in comparing the basin of New York with that of Wales. But, as I shall perhaps be able to lay before the Society such a comparison in a more detailed form, I here only present a summary of the more characteristic points. I premise these statements by the observation that both these geological areas appear to have been constructed on the same great comprehensive principles, and nearly of the same materials,—two most important considerations. One very great distinction between them, however, is, that they have received different dynamic treatment, in the frequency of plutonic disturbance in Wales and its comparative absence in New York,—such dynamic treatment involving, it must be kept in mind, both gradual and sudden changes of population. While the strata of these areas are formed of much the same mineral substances, the conditions of these, their order and quantities, are very varied. For certain leading particulars, the former portion of this Part III. may be consulted.

The points of Zoological Similarity may be summed up under the following heads or laws:—1. The organic remains of both basins belong to the same orders and genera, unmixed with those of other sedimentary systems, as Permian, Jurassic, &c. 2. Vertebrate animals were introduced at nearly the same date. 3. The organic remains approximate closely in general facies. 4. They affect strata of the same mineral character in both,—the majority preferring the calcareous, the others the arenaceous form of deposit. 5. The great majority exhibit the same order in their introduction and distribution. This is seen in *Orthis, Pentamerus, Spirifer,* and other *Brachiopoda*; and in *Endoceras, Graptolites, Trilobites, &c.*, the more highly organized being often prominent in the early stages. 6. The law of divergency into several matrices is the same, or nearly so, in the two basins, the number of instances being fewer in New York. 7. The great majority of animals typical or recurrent in one basin are so in the other. 8. The great majority of the recurrent fossils in both occupy the same number of epochs, many or few. 9. The great majority observe the same process or law of increment and decrement. This takes place in nineteen out of twenty-four orders and genera. 10. The two basins have 108 organic forms in common, including most of the genera. 11. The same orders and genera are rich and poor in species. 12. There is the same limited admission of Silurian forms into the Devonian system in New York and in Europe. 13. The plants of both are typical, with one or two exceptions.

Such are some of the great points of similarity. Now as to dissimilarity. Those which arise out of the mineral character are partly owing to physical disturbances and to a certain amount of metamorphism undergone by the Welsh strata. The palæontological differences are many, but small, often merely individual; and they seldom affect principles. They are due to the varying sea-depths and other well-known conditions.

The facts just recorded certainly indicate a close connexion, in nature and mode of formation, between the basins of New York and Wales. They seem to be quasi-equivalents—"the same, but other," to use a short and convenient phrase in common use.

This near approximation is the more surprising, when we consider under what very different circumstances the two sets of deposits were thrown down, and, further, that the nearest neighbours to the Welsh basin on the south-east and north-east are so different from it, as we see in France, on the Rhine, in Saxony and Spain—countries, which, among other differences, have often no Upper Silurian.

We seem therefore led, by analogies in other branches of natural history, to the reasonable and very interesting suggestion, that probably in early palæozoic times the eastern and western hemispheres communicated between the latitudes 42° and 52°, either by dry land or a shallow sea. This space would include western Europe, from Sweden (full of Welsh fossils) to the south of France, and of course Great Britain and Ireland, on the one side, and the State of New York, with Canada, on the other. We should then be able to account for the intimate relations existing between these two palæozoic areas, according to the laws of animal and vegetable progression from land to land.

I feel constrained to yield a waiting belief in a former continuity of land between New York and Great Britain, for the following reasons:—

That such continuity did exist at this epoch, the State Geologists of New York have inferred from the distribution of its conglomerates, grits, sandstones, clays, and limestones—those of the Middle and Upper Silurian periods especially. This distribution, together with the vestiges of certain currents impressed on rock-surfaces, appears to them to indicate the removal of large spaces of land from the site of the present Atlantic Ocean into the eastern and middle portions of North America. We draw the same conclusion from the quasi-equivalency of our two areas, as above shown.

Sir R. Murchison states, that there is at Durness, in Sutherland, a strong band of Lower Silurian limestone*, in which Mr. Peach has found well-defined animal forms belonging else only to the Lower Silurian stage of Canada. They consist of an *Oncoceras*, an *Orthoceras*, the *Maclurea Peachii*, and *Ophileta compacta*,—the last two genera being most remarkable in themselves and in their being thus found twice grouped together. We have here, therefore, an argument of some force in favour of our supposition, but which would have been very strong had these fossils of the East and the West been specifically the same, which they are not. To these facts we may add the long-ascertained relationship between the Irish and New York fossils, according to Portlock.

The greater part of the Carboniferous plants of Pennsylvania and Nova Scotia are identical with European forms; and most of the remainder are closely allied to the latter. Mr. Bunbury says that this points to a greater similarity of climate than at present obtains, and to the possible connexion of the coal-formation areas of Europe and America by groups of islands.

In all times and epochs (whether palæozoic, mesozoic, or tertiary), continuity of land, of sea, and sea-depth produced continuity or extension of life. Wherever, we proceed to say, there is discontinuity or separation of land or of sea, the opposite sides of the barriers are inhabited by different races, except in special cases.

We have hitherto spoken about community of faunæ and floræ; but now, in order to bring further into view the great importance of contours (that is, of depressions and elevations), we wish to draw attention to the extreme differences between the Silurian basins of Bohemia and Scandinavia, in their mineral and palæontological characters, as alluded to in p. 287. They all arise, in the opinions of the best-informed geologists, from the former existence of intervening coast-lines, or of great sea-depths, forbidding progression or migration.

These are subjects of the deepest interest, hitherto little looked into. I earnestly recommend them to the best attention of the young geologist. They promise splendid results—nothing less than opening the great volume of historic geology, with its successive territories and dynasties, each for a time a scene of activity and happiness, and each full of wisdom, beauty, and grandeur. We at length begin to see that we shall see.

* Quart. Journ. Geol. Soc. vol. xiv. p. 502.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cypricardia ............ | — | — | — | — | — | 1 | 5 | ... | 1 | |
| Lyrodesma ............ | — | — | — | — | — | — | 2 | | | |
| Orthonota ............ | — | — | — | — | — | — | 4 | ... | ... | 1 |
| Theca.................... | — | — | — | — | — | — | 1 | | | |

TABLE XVII.—*Numerical Table of the Silurian and Devonian Fossils of the State of New York, exhibiting their Sequence, Grouping, Increment, and Decrement; the horizontal lines being the lines of privation, marking their absence.*

| Fossils. | Potsdam S. | Calcif. S. | Chazy L. | Bird's-eye L. | Trenton L. | Utica Slate. | Hudson R. Gp. | Oneida C. | Medina S. | Clinton Gp. | Niagara Gp. | Corall. L. Scho. | Onondag. S. Gp. | Waterlime Gp. | Low. Pentamer. L. | Delthyr. Sh. L. | Upp. Pentam. L. | Oriskany S. | Caudagall. G. | Schoharie G. | Onondaga L. | Cornifer. L. | Marcellus Sh. | Hamilton Gp. | Tully Limestone. | Genesee Sl. | Portage Gp. | Chemung Gp. | Catskill Gp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plantæ | 1? | 3 | ... | 1 | 3 | 1 | 5 | ... | 5 | 13 | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | ... | ... | 1 | ... | ... | 1 | 1 | 5 | |
| Lingula | 2 | 1 | ... | ... | 9 | 3 | 1 | ... | 1 | 5 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | 2 | | | |
| Bellerophon | — | 1 | ... | ... | 5 | 1 | 2 | ... | ... | ... | 1 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | 2 | | | | | |
| Euomphalus | — | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | 1 | ... | ... | ... | ... | 1 | 1 | ... | ... | ... | ... | 1 | |
| Maclurea | — | 4 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ophileta | — | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pleurotomaria | — | 1 | 3 | 5 | 9 | 1 | 1 | ... | ... | ... | ... | 1 | 2 | ... | ... | ... | ... | ... | ... | ... | 2 | ... | ... | 2 | | | | | |
| Turbo | — | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Scalites | — | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Orthoceras | — | 3 | 8 | 2 | 20 | ... | 4 | ... | 2 | 6 | 6 | ... | 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 | 1 | ... | ... | 1 | | |
| Zoophyta | — | — | 5 | 2 | 15 | 1 | 5 | ... | 1 | 13 | 37 | 6 | 3 | ... | 1 | ... | ... | 1 | ... | ... | 12 | ... | 1 | 7 | ... | ... | ... | 4 | |
| Bryozoa | — | — | 5 | 2 | 10 | 7 | 10 | ... | ... | 14 | 29 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | | | | | |
| Crinoidea | — | — | 3 | ... | 10 | 1 | 5 | ... | ... | 8 | 28 | ... | ... | ... | ... | ... | 1 | ... | ... | ... | 1 | ... | ... | 2 | ... | ... | 1 | 2 | |
| Atrypa | — | — | 5 | ... | 18 | 2 | 2 | 1? | 2 | 20 | 16 | 4 | ... | 2 | ... | 3 | 3 | 3 | ... | ... | 3 | 3 | 2 | 9 | 7 | 2 | 1 | 16 | |
| Leptæna | — | — | 5 | 2 | 16 | 6 | 7 | ... | ... | 9 | 5 | 2 | 2 | ... | 1 | 9 | 4 | 5 | ... | ... | 4 | 6 | 4 | 13 | 1 | 1 | ... | 10 | |
| Orbicula | — | — | 1 | ... | 3 | ... | 3 | ... | ... | ... | 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | ... | 1 | ... | 1 | |
| Ambonychia | — | — | 1 | ... | 6 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| Capulus | — | — | 1 | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | 2 | | | | | | | |
| Murchisonia | — | — | 2 | 4 | 9 | ... | 3 | ... | 1 | 1 | ... | 2 | 6 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | | | | | | | |
| Metoptoma | — | — | 1 | ... | ... | ... | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Raphistoma | — | — | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endoceras | — | — | 4 | ... | 13 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| Gonioceras | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lituites | — | — | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ormoceras | — | — | 3 | ... | ... | ... | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Ceraurus | — | — | 1 | ... | ... | ... | ... | ... | ... | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Illænus | — | — | 2 | 1 | 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Isotelus | — | — | 1 | ... | 2 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Asaphus | — | — | 2 | 1 | 1 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | | | | | | | | |
| Modiolopsis | — | — | — | 1? | 10 | ... | 9 | ... | 2 | 3 | 2 | | | | | | | | | | | | | | | | | | |
| Modiola | — | — | — | 1 | ... | ... | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Bucania | — | — | — | 2 | 4 | 1 | 1 | ... | ... | 2 | ... | 2 | | | | | | | | | | | | | | | | | |
| Natica? | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Calymene | — | — | — | 1 | 4 | 3 | 2 | ... | ... | 2 | 1 | 2 | 1 | | | | | | | | | | | | | | | | |
| Ogygia? | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cytherina? | — | — | — | 1 | ... | ... | ... | ... | ... | 1 | 1 | 1 | ... | 1 | | | | | | | | | | | | | | | |
| Annelida | — | — | — | — | 1 | ... | 1 | ... | ... | 2 | 1 | ... | 2 | 2 | 1 | 2 | 1 | ... | ... | ... | ... | 1 | 1 | ... | ... | 1 | | | |
| Cystidea | — | — | — | — | 1 | ... | ... | ... | ... | ... | 5 | | | | | | | | | | | | | | | | | | |
| Spirifer | — | — | — | — | 2 | 1 | 1 | ... | ... | 3 | 10 | 3 | ... | 1 | 1 | 10 | 4 | 5 | ... | ... | 2 | 11 | ... | 19 | 1 | ... | 1 | 14 | |
| Rhynchonella | — | — | — | — | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 5 | 12 | 2 | 5 | ... | ... | 3 | | | | | | | | |
| Avicula | — | — | — | — | 3 | 1 | 3 | | | | | | | | | | | | | | | | | | | | | | |
| Pterinæa | — | — | — | — | 1 | ... | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Tellinomya | — | — | — | — | 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Cardiomorpha | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Edmondia | — | — | — | — | 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| Nuculites | — | — | — | — | 2 | ... | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Nucula | — | — | — | — | 3 | ... | 2 | | | | | | | | | | | | | | | | | | | | | | |
| Carinaropsis | — | — | — | — | 1 | ... | 2 | | | | | | | | | | | | | | | | | | | | | | |
| Cyrtolites | — | — | — | — | 4 | ... | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Holopæa | — | — | — | — | 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Subulites | — | — | — | — | 1 | ... | ... | ... | .. | ... | ... | ... | 1 | | | | | | | | | | | | | | | | |
| Cameroceras | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Cyrtoceras | — | — | — | — | 8 | ... | ... | ... | ... | ... | 1 | ... | 1 | | | | | | | | | | | | | | | | |
| Oncoceras | — | — | — | — | 1 | ... | ... | ... | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Phragmolites | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Trocholites | — | — | — | — | 1 | 1 | 2 | | | | | | | | | | | | | | | | | | | | | | |
| Conularia | — | — | — | — | 1 | ... | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | | | | | |
| Acidaspis | — | — | — | — | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| Ampyx | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bumastus | — | — | — | — | 1 | ... | ... | ... | ... | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Lichas | — | — | — | — | 1 | ... | ... | ... | ... | ... | 1 | | | | | | | | | | | | | | | | | | |
| Phacops | — | — | — | — | 3 | ... | ... | ... | ... | 2 | 1 | ... | ... | ... | 2 | ... | ... | ... | ... | ... | ... | 1 | | | | | | | |
| Platynotus | — | — | — | — | 1 | ... | ... | ... | ... | ... | 1 | | | | | | | | | | | | | | | | | | |
| Trinucleus | — | — | — | — | 2 | ... | 2 | | | | | | | | | | | | | | | | | | | | | | |
| Cleidophorus | — | — | — | — | — | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Cypricardia | — | — | — | — | — | 1 | 5 | ... | 1 | | | | | | | | | | | | | | | | | | | | |
| Lyrodesma | — | — | — | — | — | — | 2 | | | | | | | | | | | | | | | | | | | | | | |
| Orthonota | — | — | — | — | — | — | 4 | ... | ... | 1 | | | | | | | | | | | | | | | | | | | |
| Theca | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Agnostus | — | — | — | — | — | — | 2 | | | | | | | | | | | | | | | | | | | | | | |
| Homalonotus | — | — | — | — | — | — | — | — | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Chonetes | — | — | — | — | — | — | — | — | — | 1 | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | ... | 1 | ... | 5 | | | | | |
| Pentamerus | — | — | — | — | — | — | — | — | — | 3 | 1 | ... | 1 | ... | ... | 2 | 1 | ... | ... | ... | 1 | | | | | | | | |
| Stropheodonta | — | — | — | — | — | — | — | — | — | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Posidonia | — | — | — | — | — | — | — | — | — | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Cyclonema | — | — | — | — | — | — | — | — | — | 3 | ... | ... | 1 | | | | | | | | | | | | | | | | |
| Platyostoma | — | — | — | — | — | — | — | — | — | 1 | 2 | 1 | | | | | | | | | | | | | | | | | |
| Discosurus | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | |
| Beyrichia | — | — | — | — | — | — | — | — | — | 1 | 1 | | | | | | | | | | | | | | | | | | |
| Cybele | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | |
| Olenus | — | — | — | — | — | — | — | — | — | 2 | | | | | | | | | | | | | | | | | | | |
| Sphærexochus | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | | |
| Posidonomya | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | |
| Pyronomæus | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | |
| Gomphoceras | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | |
| Arges | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | |
| Bronteus | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | | | |
| Proetus | — | — | — | — | — | — | — | — | — | — | 2 | | | | | | | | | | | | | | | | | | |
| Trochoceras | — | — | — | — | — | — | — | — | — | — | — | 2 | | | | | | | | | | | | | | | | | |
| Megalomus | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | | |
| Loxonema | — | — | — | — | — | — | — | — | — | — | — | — | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | 2 | ... | ... | .. | 1 | |
| Littorina | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | | | | | | | |
| Eatonia | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | | | | | | | | | | | | | |
| Leptocelia | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | ... | 1 | | | | | | | | | | | |
| Meganteris | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3 | 1 | 2 | ... | ... | 1 | 1 | | | | | | | |
| Merista | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3 | 1 | | | | | | | | | | | | |
| Waldheimia | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3 | ... | 1† | | | | | | | | | | | |
| Cyrtia | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | ... | ... | 1 | | | | | | | | | |
| Pleurorhyncus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | | | |
| Cypricardites | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | ... | 1 | 14 | ... | .. | 1 | 1 | 2 |
| Chemnitzia | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | |
| Lucina | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | ... | 1 | ... | ... | 1 | | |
| Odontocephalus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | | | |
| Goniatites | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | 2 | ... | ... | 4 | 1 | |
| Athyris | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | ... | ... | .. | 1 | |
| Productus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 7 | 1 | ... | ... | 7 | |
| Spirigera | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | |
| Tropidoleptus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | |
| Inoceramus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | ... | ... | ... | 1 | |
| Cucullæa | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | |
| Grammysia | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | |
| Microdon | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | ... | ... | ... | 1 | |
| Cardium | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | ... | ... | 1 | | |
| Tellina? | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | |
| Phragmoceras | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | | | | |
| Cryphæus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 4 | | | | | |
| Pinnopsis | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2 | | |
| Astarte | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | | |
| Clymenia? | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | 1 | |
| Lima | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3 | |
| Pecten | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 6 | |
| Mytilus | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | |

† Maryland (*Hall*).

TABLE XVIII.—*The Silurian Fossils of the State of New York in their different Sedimentary Habitats.*

P=Potsdam Sandstone.
CS=Calciferous Sandstone.
C=Chazy Limestone.
B=Bird's-eye Limestone.
T=Trenton Limestone.
U=Utica Slate.
HR=Hudson River Rocks.
M=Medina Sandstone.
cl=Clinton Rocks.
N=Niagara Rocks.
CL=Coralline Limestone of Schoharie.
OS=Onondaga Salt Group.
W=Waterlime Group.
PL=Lower Pentamerus Limestone.
DS=Delthyris Shaly Limestone.
UP=Upper Pentamerus Limestone.

*** The Authorities followed in the determination of the sediments are chiefly Hall, Vanuxem, Emmons, and De Verneuil.

| Fossils. | 1 Siliceous Conglomerate. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandstone. | 5 Argillaceous Sandstone. | 6 Calcareous Sandstone. | 7 Ferruginous Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limestone. | 12 Argillaceous Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLANTÆ. | | | | | | | | | | | | | |
| ? Scolithus linearis | ... | ... | ... | P | | | | | | | | | |
| verticalis | ... | ... | ... | P | | | | | | | | | |
| Palæophycus tubercularis | ... | ... | ... | ... | ... | CS | | | | | | | |
| irregularis | ... | ... | ... | ... | ... | CS | | | | | | | |
| rugosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| simplex | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | | | |
| virgatus | ... | ... | ... | ... | HR | | | | | | | | |
| striatus | ... | ... | ... | ... | cl | | | | | | | | |
| tortuosus | ... | ... | ... | ... | M | | | | | | | | |
| sp. ind. | ... | ... | ... | ... | HR | | | | | | | | |
| sp. ind. | ... | ... | ... | ... | cl | | | | | | | | |
| Anthrophycus Harlani | ... | ... | ... | M | | | | | | | | | |
| sp. ind. | ... | ... | ... | M | | | | | | | | | |
| Buthrotrephis antiquata | ... | ... | ... | ... | ... | CS | | | | | | | |
| tenuis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| succulea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subnodosa | ... | ... | ... | ... | HR | | | | | | | | |
| flexuosa | ... | ... | ... | ... | HR | | | | | | | | |
| gracilis | ... | ... | ... | ... | cl | | | | | | | | |
| var. crassa | ... | ... | ... | ... | cl | | | | | | | | |
| var. intermedia | ... | ... | ... | ... | cl | | | | | | | | |
| palmata | ... | ... | ... | cl | | | | | | | | | |
| impudica | ... | ... | ... | ... | cl | | | | | | | | |
| ramosa | ... | ... | ... | ... | cl | | | | | | | | |
| Sphenothallus angustifolius | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| latifolius | ... | ... | ... | ... | HR | | | | | | | | |
| Phytopsis tubulatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| cellulosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | B |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rusophycus clavatus | ... | ... | ... | ... | cl | | | | | | | | |
| subangulatus | ... | ... | ... | ... | cl | | | | | | | | |
| pudicus | ... | ... | ... | ... | cl | | | | | | | | |
| bilobatus | ... | ... | ... | ... | cl | | | | | | | | |
| Ichnophycus tridactylus | ... | ... | ... | ... | cl | | | | | | | | |
| **Annelida.** | | | | | | | | | | | | | |
| Tentaculites distans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| flexuosus | ... | ... | ... | ... | ... | ... | HR | ... | HR | ... | ... | cl T | |
| fissurellus | ... | ... | ... | ... | ... | ... | ... | ... | ... | M | | | |
| minutus | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| ornatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | W | |
| scalaris | ... | ... | ... | ... | ... | ... | ... | ... | DS | | | | |
| Cornulites serpularius | ... | ... | ... | ... | cl | | | | | | | | |
| flexuosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| sp. ind. | ... | ... | ... | ... | ... | OS | | | | | | | |
| Gordia marina | ... | ... | ... | ... | HR | | | | | | | | |
| **Bryozoa.** | | | | | | | | | | | | | |
| Alecto inflata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Astrocerium parasiticum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| pyriforme | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| constrictum | ... | ... | ... | ... | ... | ... | ... | ... | N | N | | | |
| venustum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | |
| Ceramopora imbricata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| incrustans | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| foliacea | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Clathropora alcicornis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| frondosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| Diamesipora dichotoma | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Escharapora recta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| var. nodosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Hornera? dichotoma | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Graptolites amplexicaulis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| bicornis | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| mucronatus | ... | ... | ... | ... | HR | | | | | | | | |
| pristis | ... | ... | ... | ... | HR | | | | | | | | |
| secalinus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| furcatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| gracilis | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| ramosus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| scalaris | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| sagittarius | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| sextans | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Graptolites serratulus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| tenuis | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Clintonensis | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| lævis | ... | ... | ... | ... | U | | | | | | | | |
| venosus | ... | ... | ... | ... | cl | ... | ... | ... | cl | | | | |
| Fenestella elegans | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| cribrosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| prisca? | ... | ... | ... | ... | ... | cl | ... | ... | cl | | | | |
| tenuiceps | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| tenuis | ... | ... | ... | ... | ... | cl | | | | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Intricaria reticulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Polypora incepta | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Retepora angulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | ... | cl | |
| asperato-striata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| Clintoni | ... | ... | ... | cl | | | | | | | | | |
| diffusa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| foliacea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| gracilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| incepta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| Stictopora acuta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| crassa | ... | ... | ... | ... | ... | cl | ... | ... | ... | ... | ... | cl | |
| elegantula | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| fenestrata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| glomerata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| labyrinthica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| lanceolata (HR) | | | | | | | | | | | | | |
| punctipora | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| ramosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| raripora | ... | ... | ... | ... | ... | cl | | | | | | | |
| Stromatocerium rugosum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| Trematopora tuberculosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| aspera | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| coalescens | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| granulifera | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| punctata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| ostiolata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| solida | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| striata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| spinulosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| sparsa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| tubulosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| ZOOPHYTA. | | | | | | | | | | | | | |
| Aulopora arachnoides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Callopora elegantula | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Callopora aspera | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| florida | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| laminata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| nummiformis | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | | | |
| Caninia bilateralis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | cl | | |
| Cannapora junciformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| Catenapora escharoides | ... | ... | ... | ... | ... | ... | ... | cl | ... | ... | ... | N | |
| agglomerata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | N |
| Chætetes lycoperdon | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| columnaris | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| rugosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | M | |
| Cladopora seriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | M | |
| cæspitosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| cervicornis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| fibrosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| multipora | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| macropora | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| reticulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Columnaria alveolata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| inæqualis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| sulcata (c) | | | | | | | | | | | | | |
| Conophyllum Niagarense | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Cryptolithus tessellatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Cyathophyllum vermiculare | | | | | | | | | | | | | |
| Cyclolites rotuloides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| Dictyolites Beckii | ... | ... | ... | ... | M | | | | | | | | |
| Dictyonema gracilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| retiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Diplophyllum cæspitosum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| coralliferum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| Discophyllum peltatum | ... | ... | ... | ... | HR | | | | | | | | |
| sp. ind. | ... | ... | ... | ... | HR | | | | | | | | |
| Favistella favosidea | ... | ... | ... | ... | ... | cl? | ... | ... | ... | cl? | ... | | |
| stellata | ... | ... | ... | ... | ... | HR | | | | | | | |
| Favosites alveolaris (N) | | | | | | | | | | | | | |
| favosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Gothlandica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| lycopodites | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| Gorgonia? aspera | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| perantiqua | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Heliolites elegans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| interstincta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| macrostylus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| pyriformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| spinipora | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Helopora fragilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| Inocaulis plumosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Lichenalia concentrica | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Limaria fruticosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| laminata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| ramulosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| Phænopora explanata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| constellata? | ... | ... | ... | ... | ... | ... | ... | cl | cl | | | | |
| ensiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | |
| Porcellia ornata | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | ... | T | |
| Porites interstincta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS | |
| vetusta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Polydilasma turbinata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Rhinopora angulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl N | | | |
| tuberculosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| tubulosa | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| verrucosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | ... | cl | |
| Sagonella membranacea | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| Stellipora antheloidea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Streptelasma expansa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| corniculum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| crassa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| caligula | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| multilamellosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| parvula | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| profunda | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B? | |
| Stromatopora concentrica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| constellata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Syringopora? multicaulis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| fibrosa (N) | | | | | | | | | | | | | |
| Striatopora flexuosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Receptaculites Logani | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| CRINOIDEA. | | | | | | | | | | | | | |
| Actinocrinus tenuiradiatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| Asterias matutina | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | ... | T | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| Caryocrinus ornatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl N | |
| Closterocrinus elongatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| Cyathocrinus pyriformis | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| tuberculatus | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| Dendrocrinus longidactylus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Echinocrinites anatiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | * |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| Eucalyptocrinus decorus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eucalyptocrinus cælatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| papulosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Glyptocrinus decadactylus | ... | ... | ... | ... | ... | ... | ... | ... | HR? | | | | |
| plumosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| Glyptaster brachiatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Heterocrinites heterodactylus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| gracilis | ... | ... | ... | ... | ... | ... | ... | ... | HR? | | | | |
| simplex | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | | | |
| Heterocystites armatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| Homocrinus cylindricus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| parvus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Ichthyocrinus Clintoni | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| lævis | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| Lecanocrinus caliculus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| macropetalus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| ornatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| simplex | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Lyriocrinus dactylus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Macrostylocrinus ornatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Melocrinites sculptus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| Myelodactylus convolutus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| brachiatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Nucleocrinus Hallii | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Poteriocrinus alternatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| gracilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Saccocrinus speciosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | ... | N |
| Schizocrinus nodosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| striatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Scyphocrinus heterocostalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Stephanocrinus angulatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| gemmiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Thysanocrinus liliiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N? | | | |
| caniculatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| aculeatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| immaturus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| CYSTIDEA. | | | | | | | | | | | | | |
| Callocystites Jewettii | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Apiocystites elegans | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Hemicystites parasitica | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Palæaster Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRACHIOPODA. | | | | | | | | | | | | | |
| Lingula antiqua | ... | ... | ... | P | | | | | | | | | |
| acuminata | ... | ... | ... | ... | ... | CS | | | | | | | |
| acutirostra (cl) | | | | | | | | | | | | | |
| æqualis | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| attenuata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| crassa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| cuneata | ... | ... | ... | M | | | | | | | | | |
| curta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| elongata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| lamellata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| oblonga | ... | ... | ... | ... | cl | | | | | | | | |
| oblata | ... | ... | ... | ... | cl | | | | | | | | |
| obtusa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| ovata (T) | | | | | | | | | | | | | |
| perovata | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| prima | ... | ... | ... | P | | | | | | | | | |
| quadrata | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | ... | T | |
| riciniformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Orbicula? crassa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | |
| corrugata | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| cælata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | |
| deformata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| filosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| lamellosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subtruncata | ... | ... | ... | ... | HR | | | | | | | | |
| squamiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| tenuilamellata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| terminalis | ... | ... | ... | ... | ... | ... | ... | .. | ... | ... | ... | T | |
| Leptæna alternata | ... | ... | ... | ... | HR | ... | ... | ... | HR | ... | ... | T | |
| alternistriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| arcuata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| bipartita | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl |
| Beckii | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| camerata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| concava | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| corrugata | ... | ... | ... | ... | ... | ... | ... | ... | cl | ... | ... | cl | |
| deflecta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| deltoidea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| depressa | ... | ... | ... | ... | ... | ... | cl | ... | ... | N | ... | cl | |
| fasciata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| filitexta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Headleyana | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| imbrex | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| incrassata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Leptæna laticosta (c) | | | | | | | | | | | | | |
| Leavensworthana | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| obscura | ... | ... | ... | cl ? | ... | ... | cl | | | | | | |
| orthididæa | ... | ... | ... | ... | ... | ... | cl | | | | | | |
| patenta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| plicifera | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| planumbona | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| profunda | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| planoconvexa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| recta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subplana | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| subtenta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sericea | ... | ... | ... | ... | ... | ... | ... | ... | cl | ... | ... | T | |
| striata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| tenuilineata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| tenuistriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| transversalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Woolworthana | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| Orthis æquivalvis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| bellarugosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| bisulcata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| centrilineata | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| crenistria (cl) | | | | | | | | | | | | | |
| costalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| dichotoma | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| disparilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| elegantula | ... | ... | ... | ... | ... | ... | ... | ... | cl N | | | | |
| erratica | ... | ... | ... | ... | HR | | | | | | | | |
| fasciata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| fissicosta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| flabellulum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| hybrida | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| insculpta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| interstriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| limitaris | | | | | | | | | | | | | |
| opercularis, var. semiovalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| occidentalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| orbicularis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| pectinella | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| var. semiovalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| plicatella | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| pisum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| perveta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| punctostriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| pyramidalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| resupinata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orthis sinuata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subæquata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subjugata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subquadrata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| tenui-dens | ... | ... | ... | ... | ... | cl | cl | | | | | | |
| testudinaria | ... | ... | ... | ... | HR | ... | ... | ... | HR | ... | ... | T | |
| trinucleus | ... | ... | ... | ... | ... | ... | ... | cl | | | | | |
| tricenaria | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Verneuilii | | | | | | | | | | | | | |
| Spirifer biforatus (Lynx) | ... | ... | ... | ... | ... | ... | ... | .. | ... | cl | ... | HR | |
| bilobus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| bicostatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| concinnus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| crispus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| cyrtænus (N) | | | | | | | | | | | | | |
| duplicatus | | | | | | | | | | | | | |
| expansus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| macropleurus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| multistriatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| pyramidalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| radiatus | ... | ... | ... | ... | cl | ... | ... | cl | ... | N | ... | cl | |
| sulcatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| pachyopterus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| perforatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| plicatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | PLW | |
| zigzag | ... | ... | ... | ... | ... | ... | ... | ... | * | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| Leptocelia concava | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| imbricata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Meganteris æquiradiata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | UP | |
| elliptica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| lævis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| mutabilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Eatonia medialis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| bella | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Merista subquadrata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| lævis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | DS |
| arcuata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Atrypa acutirostra | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| æquiradiata | ... | ... | ... | ... | C | | | | | | | | |
| affinis | ... | ... | ... | ... | ... | ... | ... | cl | | | | | |
| altilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| ambigua | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| aprinis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| bidens | ... | ... | ... | ... | ... | cl? | | | | | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atrypa bidentata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| brevirostra | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| bisulcata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| canura | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| circulus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| concentrica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| congesta | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| crassirostra | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| cuspidata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| congesta | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| corallifera | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| cylindrica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| deflecta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| dentata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| didyma | ... | ... | ... | ... | ... | ... | ... | cl | | | | | |
| disparilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| dubia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| emacerata | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| exigua | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| extans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| increbrescens | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | ... | T | |
| intermedia | ... | ... | ... | ... | ... | ... | cl | ... | ... | ... | ... | cl | |
| interplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| hemiplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| hemisphærica | ... | ... | ... | ... | ... | ... | ... | ... | cl | cl | | | |
| lævis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| lamellata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| limæformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| lacunosa (PL) | | | | | | | | | | | | | |
| gibbosa | ... | ... | ... | cl | | | | | | | | | |
| glabella (T) | | | | | | | | | | | | | |
| medialis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | { | DS<br>cl | |
| modesta | ... | ... | ... | ... | ... | ... | ... | ... | ... | U | ... | T | |
| neglecta | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| naviformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| nitida | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| var. oblata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| nodostriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| nucleolata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| nucleus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| obtusiplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| oblata | ... | ... | ... | M | | | | | | | | | |
| quadricostata | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| recurvirostra | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| reticularis | ... | ... | ... | ... | ... | ... | ... | ... | N | N | ... | cl | |
| robusta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atrypa rugosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| singularis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| sordida | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subtrigonalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sulcata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | W | |
| planoconvexa | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| plicata | ... | ... | ... | ... | ... | ... | M | | | | | | |
| plicatella | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| plicatula | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| plena | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| protea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T ? | |
| plicifera | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| tumida | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| unisulcata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Waldheimia globosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| formosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Deweyi | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Stropheodonta prisca | ... | ... | ... | ... | ... | ... | cl | | | | | | |
| textilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| Chonetes cornuta | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| Megalomus Canadensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| Rhynchonella aspera (N) | | | | | | | | | | | | | |
| deflexa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| marginalis (N) | | | | | | | | | | | | | |
| Wilsoni (N) | | | | | | | | | | | | | |
| rudis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| inutilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| planoconvexa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| sulcoplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| formosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| eminens | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| ventricosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| campbellaria | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| nobilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| nucleolata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| abrupta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| vellicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| pyramidata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| altiplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| acutiplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| bi-alveolata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| transversa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rhynchonella æquivalvis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | PL | |
| semiplicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | PL | |
| mutabilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | PL | |
| Pentamerus elongatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| fornicatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| galeatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | PL | |
| ovalis | ... | ... | ... | cl | cl | | | | | | | | |
| oblongus | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | ... | cl | |
| occidentalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| pseudo-galeatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Verneuilii | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| Strophomena grandis | ... | ... | ... | ... | ... | ... | ... | ... | T | | | | |
| lævis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | BC | |
| mucronata | ... | ... | ... | ... | ... | ... | ... | ... | M ? | | | | |
| nasuta | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| pustulosa | ... | ... | ... | ... | ... | M ? | | | | | | | |
| punctilifera | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| pecten | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| radiata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| rugosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| semiovalis | ... | ... | ... | ... | ... | ... | ... | ... | T | | | | |
| setigera | ... | ... | ... | ... | ... | ... | ... | ... | M | | | | |
| MONOMYARIA. | | | | | | | | | | | | | |
| Ambonychia amygdalina | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| bellastriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| carinata | ... | ... | ... | ... | HR | | | | | | | | |
| mytiloides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| orbicularis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| obtusa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| radiata | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| undata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | ... | TU | |
| Avicula demissa | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| desquamata | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| elliptica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| emacerata | ... | ... | ... | ... | cl | ... | ... | cl | ... | cl | | | |
| insueta | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| limæformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | DS | |
| monticula | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | PL | |
| naviformis | ... | ... | ... | ... | ... | ... | ... | ... | DS | ... | ... | PL | |
| muricata | | | | | | | | | | | | | |
| orbiculata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| rugosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | W |
| securiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| subrecta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avicula subplana | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| subrecta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| rhomboidea | ... | ... | ... | cl | ... | ... | ... | ... | cl | | | | |
| Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| triquetra | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| undata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| Tellinomya curta | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| dubia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| æquilateralis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| lata | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| machæriformis | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| nasuta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| anatiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| elliptica | ... | ... | ... | ... | cl | | | | | | | | |
| gibbosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| sanguinolarioidea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Posidonomya rhomboidea | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| alata | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| Pterinæa carinata | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| suborbicularis | ... | ... | ... | ... | * | | | | | | | | |
| undata ? | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| DIMYARIA. | | | | | | | | | | | | | |
| Modiolopsis arcuatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| anodontoides | ... | ... | ... | ... | HR | HR? | ... | ... | ... | ... | HR? | | |
| carinatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| subcarinatus | ... | ... | ... | ... | cl | ... | ... | ... | ... | ... | ... | * | |
| aviculoides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| curtus | ... | ... | ... | ... | ... | HR | | | | | | | |
| faba | ... | ... | ... | HR | HR | ... | ... | ... | ... | ... | ... | T | |
| latus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| mytiloides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| modiolaris | ... | ... | ... | ... | HR | ... | ... | ... | ... | T | | | |
| nuculiformis | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| nasutus | ... | ... | ... | ... | HR | ... | ... | ... | ... | ... | ... | ... | T |
| orthonotus | ... | ... | ... | ... | M | | | | | | | | |
| ovatus | ... | ... | ... | ... | ... | cl | | | | | | | |
| parallelus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| ? primigenius | ... | ... | ... | ... | M | | | | | | | | |
| subspatulatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| subalatus | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| subalatus ? | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| terminalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| Trentonensis | ... | ... | ... | ... | ... | U | ... | ... | ... | ... | ... | T | |
| truncatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Modiolopsis undulostriatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| Modiola obtusa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| Orthonota contracta | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| curta | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| nasuta | ... | ... | ... | ... | ... | U | | | | | | | |
| parallela | ... | ... | ... | ... | ... | ... | HR | ... | HR | | | | |
| pholadis | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Cleidophorus planulatus | ... | ... | ... | ... | HR | ... | ... | ... | ... | HR | | | |
| Nuculites inflata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| faba | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Nucula alta | | | | | | | | | | | | | |
| donaciformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| levata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| poststriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Lyrodesma plana | ... | ... | ... | ... | HR | | | | | | | | |
| pulchella | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Cardiomorpha vetusta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Edmondia ventricosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subtruncata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subangulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Pyrenomæus cuneatus | ... | ... | ... | cl | ... | ... | ... | ... | cl | | | | |
| Cypricardia angustifrons | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| modiolaris | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| indenta | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | |
| sinuata | ... | ... | ... | ... | U | | | | | | | | |
| GASTEROPODA. | | | | | | | | | | | | | |
| Euomphalus uniangulatus | ... | ... | ... | ... | | CS | | | | | | | |
| sulcatus (Devon.?) (w) | | | | | | | | | | | | | |
| Loxonema Boydii | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | | | |
| Ophileta levata | ... | ... | ... | ... | ... | CS | | | | | | | |
| compacta | ... | ... | ... | ... | ... | CS | | | | | | | |
| complanata | ... | ... | ... | ... | ... | CS | | | | | | | |
| Maclurea labiata | ... | ... | ... | ... | ... | CS | | | | | | | |
| magna | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| matutina (Oph.) | ... | ... | ... | ... | ... | ... | ... | ... | ... | † | CS | | |
| sordida (Oph.) | ... | ... | ... | ... | ... | CS | | | | | | | |
| Raphistoma striata | ... | ... | ... | ... | ... | CS | | | | | | | |
| planistria | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| var. parva | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| staminea | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| striata (Maclurea) | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| Scalites angulatus | ... | ... | ... | ... | ... | CS | ... | ... | ... | ... | ... | ... | C |
| Cyclonema obsoleta | ... | ... | ... | cl | | | | | | | | | |

† Silico-magnesian limestones.

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyclonema cancellata | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| sulcata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| ventricosa | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| Natica? sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| Capulus auriformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| Turbo dilucula | ... | ... | ... | ... | ... | CS | | | | | | | |
| obscura | ... | ... | ... | ... | ... | CS | | | | | | | |
| Platyostoma, sp. ind. | ... | ... | ... | cl | | | | | | | | | |
| hemisphærica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Holopæa obliqua | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| paludinæformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| symmetrica | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| ventricosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Acroculia Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| angulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Littorina antiqua | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | W | |
| Pleurotomaria ambigua | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| antiquata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| biangulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| ? bilix | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| bispiralis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| capillaris | | | | | | | | | | | | | |
| indenta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| lenticularis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| littorea | ... | ... | ... | M | | | | | | | | | |
| nodulosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| nucleolata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| obsoleta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| percarinata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| perlata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| pervetusta | ... | ... | ... | M | | | | | | | | | |
| quadricarinata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| rotuloides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| solaroides | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| subconica | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | ... | T | |
| subtilistriata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| subdepressa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| sulcomarginata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| turgida | ... | ... | ... | ... | ... | CS | | | | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| sp. ind. | ... | ... | ... | ... | HR? | | | | | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Trochonema umbilicata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| Murchisonia abbreviata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| angustata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Murchisonia bellacincta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| bivittata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| bicincta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Boydii | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS | |
| conoidea | ... | ... | ... | ... | M | | | | | | | | |
| gracilis | ... | ... | ... | ... | ... | HR | ... | ... | HR | ... | ... | T | |
| Logani | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| longispira | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| uniangulata, var. abbreviata | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| perangulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | | |
| var. *a* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subfusiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| tricarinata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| terebralis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | CL |
| varicosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| ventricosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| vittata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| uniangulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | | | |
| subulata | ... | ... | ... | ... | ... | ... | ... | ... | cl | ... | ... | OS | |
| turritiformis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| macrospira | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS | |
| obtusa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| Subulites elongata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| ventricosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| Metoptoma? dubia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| rugosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR |
| Carinaropsis carinatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| patelliformis | ... | ... | ... | ... | ... | ... | ... | ... | * | * | ... | ... | T |
| orbiculatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| HETEROPODA. | | | | | | | | | | | | | |
| Bellerophon auriculatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| bilobatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | ... | T | |
| var. acutus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| var. corrugatus | ... | ... | ... | ... | ... | CS | ... | ... | ... | ... | ... | T | |
| cancellatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| profundus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| punctifrons | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sulcatinus | ... | ... | ... | ... | ... | CS | | | | | | | |
| Bucania angustata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| bellapunctata | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| bidorsata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| expansa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| intexta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| rotundata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| punctifrons | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bucania sulcatina | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| trilobata | ... | ... | ... | M | ... | ... | cl | | | | | | |
| stigmosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| Cyrtolites compressus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| filosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| ornatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Ellipsolites | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| Pteropoda. | | | | | | | | | | | | | |
| Conularia gracilis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| granulata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| longa | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| papillata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Theca triangularis | ... | ... | ... | ... | ... | ... | ... | ... | HR | HR | | | |
| Forbesii (PL) | | | | | | | | | | | | | |
| Cephalopoda. | | | | | | | | | | | | | |
| Lituites undatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| convolvans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| Trocholites ammonius | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | ... | T | |
| planorbiformis | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Oncoceras constrictum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| expansum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| gibbosum | ... | ... | ... | ... | M | | | | | | | | |
| subrectum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | |
| Cyrtoceras annulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| arcte-cameratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| arcuatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| camurum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| cancellatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| constricto-striatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| lamellosum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| macrostomum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| multicameratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Orthoceras abruptum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| æquale | ... | ... | ... | ... | * | | | | | | | | |
| amplicameratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| annellum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| annulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| arcuoliratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | T |
| articulatum | | | | | | | | | | | | | |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Orthoceras bilineatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| var. *α*. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| cancellatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| clathratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| clavatum | ... | ... | ... | ... | cl | | | | | | | | |
| coralliferum | ... | ... | ... | ... | HR | ... | ... | ... | U | | | | |
| duplex | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| fusiforme | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| ? imbricatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| junceum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| læve | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS | |
| lamellosum | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| laqueatum | ... | ... | ... | ... | ... | CS | ... | ... | ... | ... | ... | T | |
| var. *α*. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| latiannulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| multicameratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| moniliforme | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| multilineatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| multiseptum | ... | ... | ... | ... | M | | | | | | | | |
| primigenium | ... | ... | ... | ... | ... | CS | | | | | | | |
| rectiannulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| recticameratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| strigatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subarcuatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| tenuiseptum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| teretiforme | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| textile | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| undulostriatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| undulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| vertebrale | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| vertebratum (ccl) | | | | | | | | | | | | | |
| virgatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| virgulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | |
| sp. ind. | ... | ... | ... | ... | M | | | | | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| Ormoceras crebriseptum | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| gracile | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| tenuifilum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| var. distans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| vertebratum | ... | ... | ... | ... | ... | cl | | | | | | | |
| Endoceras annulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| arctiventrum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| angusticameratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| approximatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Endoceras distans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| duplicatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| longissimum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| gemelliparum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| magniventrum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| multitubulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| proteiforme | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| var. elongatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| var. lineolatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| var. strangulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| var. tenuitextum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| subcentrale | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| Phragmolites compressus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Phragmoceras (CL) | | | | | | | | | | | | | |
| Cameroceras Trentonense | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| Gonioceras anceps | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C | |
| Gomphoceras | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| Trochoceras Gebhardii | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| turbinata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| Discosurus conoideus | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | | |
| Myalina mytiliformis | ... | ... | ... | † | | | | | | | | | |
| **Crustacea.** | | | | | | | | | | | | | |
| Cytherina? cylindrica | ... | ... | ... | cl | | | | | | | | | |
| alta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL |
| spinosa | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| Agnostus lobatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | HR | |
| pisiformis | ... | ... | ... | ... | HR | | | | | | | | |
| Beyrichia lata | ... | ... | ... | ... | ... | ... | cl | cl | ... | cl | | | |
| symmetrica | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Ampyx (T) | | | | | | | | | | | | | |
| Acidaspis Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| spinigera | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Arges phlyctænodes | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Asaphus extans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | |
| largimarginatus | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| marginalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| nodostriatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T |
| obtusus | ... | ... | ... | ... | ... | CS | | | | | | | |
| Bronteus Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N |
| Bumastus Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Barriensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| Calymene Beckii | ... | ... | ... | ... | ... | ... | ... | ... | U | ... | ... | T | |
| Blumenbachii | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |

† Upper grey sandstone, Clinton group.

Table XVIII. (*continued*).

| Fossils. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Calcareous Grit. | 4 Siliceous Sandst. | 5 Argill. Sandstone. | 6 Calcar. Sandstone. | 7 Ferrug. Sandstone. | 8 Iron-Ore. | 9 Argillaceous Shale. | 10 Calcareous Shale. | 11 Siliceous Limest. | 12 Argill. Limestone. | 13 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calymene Blum., var. Niagarensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| var. senaria | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| camerata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | CL | |
| Clintoni | ... | ... | ... | ... | ... | ... | ... | cl | cl | | | | |
| Fischeri (T) | | | | | | | | | | | | | |
| multicosta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| punctata, (T.cl) | | | | | | | | | | | | | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | OS |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | U | | | | |
| Ceraurus pleurexanthemus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| insignis | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| pustulosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| vigilans | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| sp. ind. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| Cybele punctata | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | |
| Hemicrypturus Clintoni | ... | ... | ... | ... | ... | ... | ... | cl | | | | | |
| Homalonotus delphinocephalus | ... | ... | ... | ... | cl | ... | cl | ... | ... | N | | | |
| Illænus arcturus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| crassicauda | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | TC? |
| latidorsalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| ovatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Isotelus canalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | C |
| gigas | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| planus (T) | | | | | | | | | | | | | |
| Lichas Boltoni | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| laciniatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | |
| Ogygia vetusta | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B |
| Olenus asaphoides | ... | ... | ... | ... | HR | | | | | | | | |
| undulostriatus | ... | ... | ... | ... | ... | ... | ... | ... | HR | | | | |
| Phacops callicephalus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| laticaudus | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| limulurus | ... | ... | ... | ... | ... | cl | | | | | | | |
| macrophthalmus (UPL) | | | | | | | | | | | | | |
| trisulcatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | cl | | | |
| Proetus corycæus | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | | | |
| Stokesii | ... | ... | ... | ... | ... | ... | ... | ... | ... | N | ... | N | |
| Platynotus Trentonensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | T | |
| Sphærexochus mirus (cl) | | | | | | | | | | | | | |
| Trinucleus Caractaci | ... | ... | ... | ... | ... | ... | { | HR T | | | | | |
| concentricus | ... | ... | ... | ... | ... | ... | ... | ... | HR | ... | ... | T | T |
| Eurypterus remipes | ... | ... | ... | ... | OS | | | | | | | | |
| Ceratiocaris (Onchus) Deweyii | ... | ... | ... | ... | ... | ... | ... | ... | N | | | | |
| Ichthyodorulite | ... | ... | ... | ... | cl | | | | | | | | |

Table XIX.—*Silurian Fossils of Wales and the adjacent English Counties, arranged according to their Mineral Habitats.*

[Certain micaceous and ferruginous conditions of the rocks are not here noticed, on the supposition that they were produced (especially the latter) after the formation of the deposit.]

| Genera and Species. † The names marked with an obelisk indicate Fossils which do not occur in Wales, but are found in other parts of Great Britain and Ireland. | 1 Siliceous Conglomerate. | 2 Siliceous Grit. | 3 Siliceous Sandstone. | 4 Calcareous Sandstone (Earthy Limestone). | 5 Argillaceous Sandstone. | 6 Calcareo-argillaceous Shale. | 7 Mudstone. | 8 Carbonaceous Shale. | 9 Argillo-calcareous Shale. | 10 Argillaceous Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plantæ.** | | | | | | | | | | | |
| Actinophyllum plicatum | ... | ... | ... | ... | ... | ... | * | | | | |
| Cruziana semiplicata | ... | * | | | | | | | | | |
| Fucoides, n. s. | ... | * | | | | | | | | | |
| Lycopodiaceæ? (spores) | * | * | * | | | | | | | | |
| Palæochorda major | ... | ... | * | | | | | | | | |
| minor | ... | ... | * | | | | | | | | |
| teres | ... | ... | * | | | | | | | | |
| Spongarium æquistriatum | ... | ... | * | | | | | | | | |
| Edwardsi | ... | ... | * | | | | | | | | |
| interruptum | ... | ... | * | | | | | | | | |
| Trichoides ambiguus | ... | ... | ... | ... | * | | | | | | |
| **Amorphozoa.** | | | | | | | | | | | |
| Cliona (Vioa) prisca | ... | ... | ... | ... | * | | | | | | |
| Cnemidium tenue | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Stromatopora striatella | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| **Zoophyta.** | | | | | | | | | | | |
| Acervularia ananas | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Alveolites Grayi | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Labechii | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| repens | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| seriatoporides | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Arachnophyllum typus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Aulacophyllum mitratum | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Chætetes Fletcheri | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| pulchellus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Petropolitanus | ... | ... | ... | * | | | | | | | |
| Cladocora sulcata | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Clisiophyllum vortex | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Cœnites intertextus | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| juniperinus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| labrosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cœnites linearis | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| strigatus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Cyathaxonia Siluriensis | ... | ... | ... | ... | * | | | | | | |
| Cyathophyllum angustum | ... | ... | ... | ... | ... | * | | | | | |
| articulatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| flexuosum | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Loveni | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| truncatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * |
| Cystiphyllum brevilamellatum | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| cylindricum | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Grayi | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * |
| Siluriense | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Diphyphyllum flexuosum | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Favosites alveolaris | * | * | * | * | * | * | * | * | * | * | |
| cristata | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Gothlandica | ... | ... | ... | * | * | * | ... | ... | ... | * | |
| Hisingeri | ... | ... | ... | * | ... | ... | ... | ... | ... | * | |
| multipora | ... | ... | ... | ... | * | | | | | | |
| Fistulipora decipiens | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Goniophyllum Fletcheri | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| pyramidale | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Halysites catenularius | ... | ... | ... | * | * | * | * | ... | * | * | * |
| Heliolites Grayi | ... | ... | ... | ... | ... | * | ... | ... | ... | * | |
| inordinatus | ... | ... | ... | ... | ... | * | ... | ... | * | | |
| interstinctus | ... | ... | ... | * | * | ... | ... | * | * | * | |
| megastoma | ... | ... | ... | * | * | ... | ... | ... | * | * | |
| patelliformis | ... | ... | ... | ... | ... | * | ... | ... | * | * | |
| subtilis | ... | ... | ... | * | | | | | | | |
| tubulatus | * | ... | ... | * | ... | ... | ... | ... | ... | * | |
| ? discoideus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Labechia conferta | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| Lonsdaleia Wenlockensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Nebulipora Bowerbankii | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| explanata | ... | ... | ... | * | | | | | | | |
| favulosa | ... | ... | ... | * | | | | | | | |
| var. lens | ... | ... | ... | * | * | | | | | | |
| papillata | ... | ... | ... | * | ... | * | ... | ... | * | * | |
| Omphyma turbinatum | ... | ... | ... | ... | ... | * | ... | ... | * | | |
| Palæocyclus Fletcheri | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| porpita | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| præacutus | ... | ... | ... | * | * | * | ... | ... | * | * | |
| rugosus | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Petraia æquisulcata | ... | ... | ... | * | * | ... | ... | ... | * | | |
| bina | ... | ... | ... | * | ... | * | ... | ... | * | | |
| elongata | ... | ... | ... | * | | | | | | | |
| rugosa | ... | ... | ... | * | | | | | | | |
| subduplicata | * | * | * | * | * | * | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Petraia subduplicata, var. crenulata | * | * | * | * | * | * | | | | | |
| uniserialis | | | | * | * | | | | | | |
| Ptychophyllum patellatum | | | | | | | | | | * | |
| Pyritonema fasciculus | | | | | | | | | * | | |
| Sarcinula organum | | | | | | | | | * | * | |
| Stenopora fibrosa | * | * | * | * | * | * | | | * | * | |
| var. incrustans | | | | * | * | * | | | | | |
| var. Lycoperdon | | | | * | * | * | | | * | * | |
| Strephodes Craigensis | | | | | | | | | | * | |
| pseudoceratites | | | | | | | | | | * | |
| trochiformis | | | | | | | | | | | * |
| vermiculoides | | | | | | | | | | * | * |
| Syringopora bifurcata | | | | | | | | | | * | |
| fascicularis | | | | * | | | | | | | * |
| serpens | | | | | * | | | | * | | * |
| Lonsdaleana | | | | | | | | | | * | |
| Thecia Grayana | | | | | | | | | | * | |
| Swindernana | | | | | | | | | | * | |
| Zaphrentis ? (Caninia) lata | | | | | | | | | | * | |
| ECHINODERMATA. | | | | | | | | | | | |
| Actinocrinus pulcher | | | | | | * | | | | | |
| Agelacrinus Buchianus | | | | * | | | | | | | |
| Apiocystites pentremitoides | | | | | | | | | | * | |
| Cophinus dubius | | | | | | * | | | | | |
| Crotalocrinus rugosus | | | | | | | | | | * | |
| Cyathocrinus arthriticus | | | | | | | | | | * | |
| capillaris | | | | | | | | | | * | |
| (Poteriocrinus) Dudleyensis | | | | | | | | | | * | |
| goniodactylus | | | | | | | | | | * | |
| Dimerocrinus decadactylus | | | | | | | | | * | * | |
| icosidactylus | | | | | | | | | | * | |
| Echino-encrinites armatus | | | | | | | * | | | * | |
| baccatus | | | | | | | | | | * | |
| Echinosphærites arachnoideus | | | | * | | | | | | | |
| aurantium | | | | * | | | | | | | |
| Balticus | | | | * | | | * | | * | * | |
| Davisii | | | | * | | | | | | * | |
| (Caryocystites) granatum | | | | * | | | | | | | |
| Enallocrinus punctatus | | | | | | | | | | * | |
| Eucalyptocrinus decorus | | | | | | | | | | * | |
| granulatus | | | | | | | | | | * | |
| polydactylus | | | | | | | | | | * | |
| Glyptocrinus? basalis | | | | * | * | | | | | | |
| expansus | | | | | | | | | | * | |
| (Trochocrinus) lævis | | | | | * | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hemicosmites oblongus ... ... ... ... | ... | ... | ... | * | | | | | | | |
| pyriformis ... ... ... ... ... ... | ... | ... | ... | * | | | | | | | |
| squamosus ... ... ... ... ... ... | ... | ... | ... | * | | | | | | | |
| Ichthyocrinus pyriformis ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Ischadites Kœnigii ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | ... | ... | * | |
| Lepidaster Grayii... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Macrostylocrinus, sp. ... ... ... ... ... | ... | ... | * | | | | | | | | |
| Marsupiocrinus cælatus ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Paleaster asperrimus ... ... ... ... ... | ... | ... | ... | ... | * | | | | | | |
| coronella ... ... ... ... ... ... ... | ... | ... | * | | | | | | | | |
| Palechinus Phillipsii ... ... ... ... ... | * | | | | | | | | | | |
| Palæocoma Colvini ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| cygnipes ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Marstoni ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| (Bdellacoma) vermiformis... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Palæodiscus ferox... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Palasterina primæva ... ... ... ... ... | ... | ... | ... | ... | * | * | * | | | | |
| Periechocrinus articulosus ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| moniliformis ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Pisocrinus ? ornatus ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| pilula ... ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Platycrinus (Actinocrinus) retiarius ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Pleurocystites (Glyptocystites) Rugeri ... | ... | * | * | * | | | | | | | |
| Protaster leptosoma ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Miltoni ... ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Salteri ... ... ... ... ... ... ... ... | ... | ... | ... | * | | | | | | | |
| Prunocystites Fletcheri ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Pseudocrinites bifasciatus ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| magnificus ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| oblongus ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| quadrifasciatus ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Rhodocrinus ? quinquangularis ... ... ... | ... | ... | ... | * | | | | | | | |
| Rhopalocoma pyrotechnica... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Sphæronites Litchi ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| munitus ... ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| punctatus... ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| pyriformis ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Taxocrinus Orbignyi ... ... ... ... ... | ... | ... | ... | * | | | | | | | |
| tesseracontadactylus ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| tuberculatus ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Tetragonis Danbyi ... ... ... ... ... | ... | ... | * | | | | | | | | |
| Tetramerocrinus formosus ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * |
| ANNELIDA. | | | | | | | | | | | |
| Arenicolites (Scolites) linearis ... ... ... | ... | * | * | | | | | | | | |
| didymus ... ... ... ... ... ... ... ... | ... | ... | * | | | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chondrites ? acutangulus | | | * | | | | | | | | |
| ? informis | | | * | | | | | | | | |
| Cornulites serpularius | * | * | * | * | * | * | * | *? | * | * | * |
| Crossopodia lata | | * | | | | | | | | | |
| Lumbricaria antiqua † | | | | | * | | | | | | |
| gregaria † | | | | | * | | | | | | |
| Myrianites Macleayi | | | | | | * | | | | | |
| tenuis | | | | | | * | | | | | |
| Nemertites Ollivantii | | | | | | * | | | | | |
| Nereites Cambrensis | | | | | | * | | | | | |
| multiforis | | | | | | * | | | | | |
| Sedgwickii | | | | | | * | | | | | |
| Serpulites curtus | | | | | | | | | * | | |
| dispar | | | | | * | | | | | | |
| longissimus | | | | * | * | * | | | | | |
| perversus | | | | * | | | | | | | |
| MacCullochii | | | | | | | | | | | |
| Spirorbis Lewisii | | | | | | * | | | * | | |
| Tentaculites Anglicus | * | * | * | * | * | * | * | | | | |
| ornatus | | | | | | | | | * | * | * |
| tenuis | | | | | | | * | | | * | |
| Trachyderma antiquissima | | * | | | | | | | | | |
| coriacea | | | | | | * | | | | | |
| lævis | | | | * | | | | | | | |
| squamosa | | | | | | * | | | | | |
| **Crustacea.** | | | | | | | | | | | |
| Acidaspis Barrandii | | | | | | | | | | * | |
| bispinosa | | | | | | | | | | * | |
| Brightii | | | | * | | * | | | * | * | |
| Caractaci | | | | * | | | | | | | |
| coronata | | | | | | * | * | | | | |
| crenata | | | | | | | | | | * | |
| Dama | | | | | | | | | | * | |
| dumetosa | | | | | | | | | | * | |
| hystrix | | | | | | * | | | | | |
| Jamesii | | | | | | | | * | | | |
| Lalage | | | | | | * | | | | | |
| quinquespinosa | | | | | | | | | | * | |
| unica | | | | | | * | | | | | |
| Æglina binodosa | | | | | | | | * | | | |
| grandis | | | | | | | | * | | | |
| major | | | | | | * | * | * | | | |
| mirabilis | | | | | | | | | | * | |
| Agnostus limbatus | | | | | | * | | | | | |
| Maccoyi | | | | | | | | * | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agnostus pisiformis ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | * | | | |
| trinodus ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| n. sp. ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | * | | | |
| Ampyx mammillatus ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | * | | | |
| nudus ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | * | | | |
| parvulus ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | | | | |
| tumidus ... ... ... ... ... ... ... | ... | ... | ... | * | ... | ... | ... | ... | ... | * | |
| Angelina Sedgwickii ... ... ... ... ... | ... | ... | * | | | | | | | | |
| subarmata ... ... ... ... ... ... | ... | ... | * | | | | | | | | |
| Asaphus gigas † ... ... ... ... ... ... | ... | ... | ... | ... | * | | | | | | |
| læviceps †... ... ... ... ... ... ... | ... | ... | ... | ... | * | | | | | | |
| laticostatus ... ... ... ... ... ... | ... | ... | ... | * | | | | | | | |
| Powisii ... ... ... ... ... ... ... | ... | ... | * | * | * | * | ... | ... | * | * | |
| rectifrons... ... ... ... ... ... ... | ... | ... | ... | ... | * | | | | | | |
| tyrannus ... ... ... ... ... ... ... | ... | * | * | * | * | * | * | * | * | * | |
| Beyrichia affinis ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | | | | | |
| Barrandiana ... ... ... ... ... ... | ... | ... | ... | ... | * | | | | | | |
| bicornis ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | | | | |
| complicata ... ... ... ... ... ... | ... | ... | ... | * | * | * | * | * | * | * | |
| Klœdeni ... ... ... ... ... ... ... | * | * | * | * | * | * | * | ... | * | * | * |
| seminulum ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | | | | | |
| siliqua ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | | | | |
| strangulata ... ... ... ... ... ... | ... | ... | ... | * | * | ... | ... | ... | ... | * | |
| Bronteus hibernicus † ... ... ... ... ... | ... | ... | ... | ... | * | | | | | | |
| laticauda ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Calymene Blumenbachi ... ... ... ... | ... | ... | * | * | * | * | * | ... | * | * | |
| brevicapitata ... ... ... ... ... ... | ... | ... | ... | * | * | * | ... | ... | ... | *? | |
| duplicata ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | ... | * | | | |
| obtusa † ... ... ... ... ... ... ... | ... | ... | * | | | | | | | | |
| parvifrons ... ... ... ... ... ... | ... | ... | * | ... | ... | * | | | | | |
| tuberculosa ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | * | ... | ... | * | |
| Ceratiocaris ellipticus ... ... ... ... ... | ... | ... | * | | | | | | | | |
| inornatus... ... ... ... ... ... ... | ... | ... | * | | | | | | | | |
| leptodactylus ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Murchisoni ... ... ... ... ... ... | ... | ... | ... | ... | ... | * | | | | | |
| papilio ... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |
| Cheirurus bimucronatus ... ... ... ... | ... | ... | ... | * | * | ... | ... | ... | * | * | |
| cancrurus † ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| clavifrons... ... ... ... ... ... ... | ... | ... | ... | * | ... | ... | ... | ... | ... | * | |
| gelasinosus ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| octolobatus ... ... ... ... ... ... | ... | ... | ... | * | ... | ... | ... | ... | * | | |
| Sedgwickii ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | * | | | |
| Conocephalus invitus ... ... ... ... ... | ... | ... | ... | ... | ... | ... | ... | * | | | |
| Cybele rugosa ... ... ... ... ... ... | * | ... | * | * | * | | | | | | |
| verrucosa... ... ... ... ... ... ... | * | ... | * | * | * | | | | | | |
| Cyphaspis megalops ... ... ... ... ... | ... | ... | ... | * | ... | * | ... | ... | ... | * | |
| pygmæus... ... ... ... ... ... ... | ... | ... | ... | ... | ... | ... | * | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyphoniscus socialis | | | | | | | | | | | * |
| Cythere? umbonata | | | | * | * | * | | | * | * | |
| ? phaseolus† | | | | | | | | | | * | * |
| Cytheropsis Aldensis | | | | | | | | | * | * | * |
| Deiphon Forbesii | | | | | | | | | | * | |
| Dithyrocaris? aptychoides† | | | | | | | | * | | | |
| Ellipsocephalus depressus | | | | | | | | * | | | |
| Encrinurus baccatus† | | | | | * | | | | | | |
| multisegmentatus | | | | * | * | | | | | | |
| punctatus | * | * | * | * | * | * | * | | * | * | |
| sexcostatus | | | | * | * | * | | * | * | | |
| variolaris | | | | | | * | * | * | * | * | |
| Eurypterus abbreviatus | | | | * | | | | | | | |
| acuminatus | | | | | | * | | | | | |
| cephalaspis | | | * | | | | | | | | |
| chartarius | | | | | | | * | | | | |
| lanceolatus | | | | | | | * | | | | |
| linearis | | | | | | * | | | | | |
| megalops | | | | | | * | | | | | |
| pygmæus | | | | * | * | * | * | | | | |
| Harpes Dorani† | | | | | * | | | | | | |
| Flanagani† | | | | | * | | | | | | |
| Homalonotus bisulcatus | | | | * | * | * | * | | | | |
| delphinocephalus | | | | | | | | | | * | |
| Knightii | | | | * | * | * | | | | | |
| rudis | | | | * | * | | | | | | |
| Vulcani | | * | | | | | | | | | |
| Hymenocaris vermicauda | | | * | | | | | | | | |
| Illænus Barriensis | | | | | | | | | * | * | |
| Bowmanni | | | | * | * | * | | | | | |
| Davisii | | | | | | | | | | * | |
| Murchisoni | | | | | | | | * | * | | |
| ocularis† | | | | | | | | | | * | * |
| perovalis | | | | | | | | * | | | |
| Portlockii† | | | | | * | | | | | | |
| Leperditia marginata? | | | | * | * | | | | | | |
| Solvensis | | | | | | | | * | | | |
| Lichas Anglicus | | | | * | * | * | | | * | * | |
| Barrandii | | | | | | | | | | * | |
| Grayii | | | | | | | | | | * | |
| hirsutus | | | | | | | | | | * | |
| laciniatus | | | | | | | | | | * | |
| laxatus | | | * | * | * | * | | | * | * | |
| nodulosus | | | | * | | | | | * | | |
| Salteri | | | | | | | | | | * | |
| verrucosus | | | | | | | | | | * | |
| Limuloides, sp. | | | * | | | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ogygia Buchii | | | | | | | * | * | * | * | |
| Corndensis | | | | | | | | * | | | |
| Portlockii | | | | | | | * | | | | |
| scutatrix | | | | | | * | | | | | |
| Selwynii | | | | | * | * | * | * | | | |
| Olenus alatus | | | | | | | | * | | | |
| bisulcatus | | | | | | | | * | | | |
| humilis | | | | | | | | * | | | |
| micrurus | | | * | | | | * | * | | | |
| scarabæoides | | | | | | | | * | | | |
| Paradoxides Forchhammeri | | | | | | | | * | | | |
| Phacops alifrons | | | | * | | | | | | | |
| amphora | | | | | | | | | | * | |
| apiculatus | | | * | * | * | * | | | | | |
| Brongniartii | | | | * | | | | | | | |
| caudatus | | | | * | * | * | * | | * | * | |
| conophthalmus | | | | * | * | * | | | | * | |
| Dalmanni † | | | | * | | | | | | | |
| Downingii | | | | * | * | * | | | * | * | |
| Jamesii † | | | | | | * | | | | | |
| Jukesii † | | | | * | | | | | | | |
| longicaudatus | | | | | | * | * | | * | | |
| mucronatus | | | | | * | * | * | | * | | |
| obtusicaudatus | | | | | | * | | | | | |
| Stokesii | | | | * | * | * | * | | * | * | |
| sublævis † | | | | * | | | | | | | |
| truncatocaudatus | | | | | * | * | | | | | |
| Weaveri | | | | * | * | * | | | * | | |
| Proetus latifrons | | | | * | * | * | * | | * | * | * |
| Stokesii | | | | | | | | | | * | * |
| Protichnites Scoticus † | | | * | | | | | | | | |
| Pterygotus acuminatus | | | | | | * | * | | | | |
| Anglicus | | * | * | | * | | | | | | |
| arcuatus | | | | | | | * | | | | |
| gigas | | | | * | * | | | | | | |
| problematicus | | | * | * | * | * | | | | | |
| punctatus | | | | | | | * | | | | |
| stylops | | | | | * | | | | | | |
| Ludensis | | | | | | * | | | | | |
| (Subgenus Erettopterus.) | | | | | | | | | | | |
| Banksii | | | | | * | | | | | | |
| bilobus | | | | | | | * | | | | |
| perornatus † | | | | | | | * | | | | |
| var. plicatissimus † | | | | | | | * | | | | |
| Parka decipiens | | | | | * | | | | | | |
| Remopleurides Colbyi | | | | | * | * | | | | | |
| dorso-spinifer † | | | | | * | * | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcar. Sandstone (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Remopleurides latero-spinifer † | | | | | * | * | | | | | |
| longicostatus † | | | | | | * | * | | * | | |
| obtusus | | | | | | * | | | | | |
| platyceps † | | | | | | * | | | | | |
| radians | | | | | | * | | | * | * | |
| Sphærexochus mirus | | | | | | | | | * | * | * |
| sp. | | | | | * | | | | | | |
| Staurocephalus globiceps | | | | | | * | | | | | |
| Murchisoni | | | | | | * | * | | * | * | |
| Stygina latifrons | | | | | | | * | | | | |
| Murchisoni | | | | | | | | * | | | |
| Tiresias insculptus † | | | | | | | | | | * | |
| Trinucleus concentricus | * | * | * | * | * | * | * | | * | | |
| fimbriatus | | | | | | * | * | * | | | |
| Gibbsii | | | | | | | * | * | | | |
| Lloydii | | | | * | * | * | * | * | * | | |
| Murchisoni | | | | | | | * | | | | |
| radiatus | | | | | | * | * | * | | | |
| seticornis | | | | * | * | * | * | | * | * | * |
| Thersites † | | | | | | * | | | | | |
| **BRYOZOA.** | | | | | | | | | | | |
| Cellepora favosa | | | | | | | | | | * | |
| Ceriopora affinis | | | | | | | | | | * | |
| granulosa | | | | | | | | | | * | |
| Diastopora heterogyra | | | | * | | | | | | | |
| irregularis † | | | | | | | | | | * | |
| Dichograpsus Sedgwickii | | | | | | | | * | | | |
| Dictyonema (Graptopora) sociale | | | | | | | * | * | | | |
| Didymograpsus caduceus | | | | | | * | | | | | |
| geminus | | | | | | | * | * | | | |
| Murchisoni | | | | | | | *‖ | *‖ | | | |
| sextans | | | | | | | | * | | | |
| Diplograpsus bullatus | | | * | | | | | | | | |
| foliaceus | | | | | * | * | * | * | * | | |
| folium | | | | | | | | * | | | |
| mucronatus † | | | | | | | * | * | | | |
| nodosus † | | | | | | | | * | | | |
| pennatus † | | | | | | | | * | | | |
| pristis | | | | * | | * | * | * | * | * | |
| ramosus † | | | | | | | | * | | | |
| rectangularis | | | | | | | | * | | | |
| teretiusculus | | | | | | | * | * | | | |
| Discopora antiqua | | | | | | | | | | * | |

‖ Young state.

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Discopora favosa | | | | | | | | | | * | |
| squamata | | | | | | | | | * | * | |
| Escharina? angularis | | | | | | | | | | * | |
| Fenestella assimilis | | | | | | | | | * | * | |
| capillaris † | | | | | * | | | | | | |
| Lonsdalei | | | | | | | | | | * | |
| Milleri | | | | | | * | * | | | * | |
| patula | | | | | | | | | | * | |
| regularis † | | | | | * | | | | | | |
| reticulata | | | | | | | | | | * | |
| rigidula | | | | | | | | | | * | |
| subantiqua | | | | | | | | | | * | |
| undulata † | | | | | * | | | | | | |
| Glauconome disticha | | | | | | * | * | | * | * | |
| Graptolithus Conybeari † | | | | | * | * | | | | | |
| Flemingii | | | | | | | * | | | | |
| Griestonensis † | | | | | | * | * | | | | |
| latus | | | | | | | * | * | | | |
| lobiferus † | | | | | | | | * | | | |
| Nicoli † | | | | | | | | * | | | |
| Nilssoni | | | | | | | | * | | | |
| priodon | | * | * | * | * | * | * | * | * | | |
| sagittarius † | | | | | | | | * | | | |
| Sedgwickii † | | | | | * | * | * | * | | | |
| tenuis † | | | | | | * | * | | | | |
| Heteropora? crassa | | | | | | | | | | * | |
| Intricaria obscura † | | | | | * | | | | | | |
| Nidulites favus | | | | * | * | | | | | | |
| Polypora crassa | | | | | | | | | | * | |
| Protovirgularia dichotoma † | | | | | *? | | | * | | | |
| Ptilodictya acuta | | | | | * | * | | | | * | * |
| costellata | | | | | * | | | | | | |
| dichotoma | | | | * | * | * | | | | | |
| explanata | | | | * | * | * | | | | | |
| fucoides | | | | * | * | | | | | | |
| lanceolata | | | | | | * | | | * | * | |
| scalpellum | | | | | | * | | | * | | |
| Rastrites Barrandii † | | | | | | | | * | | | |
| peregrinus † | | | | | | | | * | | | |
| Retepora Hisingeri | | | | * | * | * | | | | | |
| infundibulum | | | | | | | | | | * | |
| Retiolites Geinitzianus † | | | | | | | | | * | | |
| venosus | | | | | | | | * | | | |
| Aulopora consimilis | | | | | | | | | | * | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brachiopoda.** | | | | | | | | | | | |
| Athyris Circe | | | | | | | | | | * | |
| ? obovata | | | | | | | * | | | * | |
| tumida | | | | * | * | * | * | | * | * | |
| ? crassa | | | | | | * | * | | | | |
| hemisphærica | | | | * | * | | | | | | |
| marginalis | * | | | * | * | * | * | * | * | * | * |
| orbicularis | * | * | * | * | * | * | | | | | |
| reticularis | * | * | * | * | * | * | * | | * | * | * |
| Chonetes lata | | | * | | * | * | | | | * | |
| Crania craniolaris | | | | | * | | | * | | | |
| divaricata | | | | | | | | | * | * | |
| Sedgwickii | | | | | | | | | | * | |
| Discina crassa | | | * | | | | | * | * | | |
| Forbesii | | | | | | | | | | * | |
| implicata | | | * | | * | * | * | | * | * | |
| lævigata | | | | | * | | | | | | |
| Morrisii | | | | | | | | | * | | |
| oblongata | | | | * | * | | | | | | |
| perrugata | | | | | * | | | | | | |
| punctata | | | | * | | | | | | | |
| rugata | | * | | | * | * | | | | | |
| striata | | | | | * | | | | | | |
| subrotunda | | | | | * | | | | | | |
| Verneuilii | | | | | | | | | | * | |
| Leptæna Fletcheri | | | | | | | | | | * | |
| lævigata | | | | * | * | * | | | | | |
| lævissima | | | | | | * | | | | | |
| minima | | | | * | | | * | | * | | |
| quinquecostata | | | | * | * | * | | | * | * | |
| scissa | | | | * | * | * | | | * | | |
| sericea | * | * | * | * | * | | | | | | |
| sublævis | | | | | | | | | * | * | |
| tenuicincta | | | | * | * | * | | | * | * | |
| transversalis | | | * | * | * | * | * | | * | * | |
| ungula | | | | * | | | | | | | |
| Lingula attenuata | | | | * | | * | | * | * | * | |
| brevis | | | | | * | | | | | | |
| cornea | | | * | * | * | * | | | | | |
| crumena | | * | * | | | | | | | | |
| Davisii | | | * | | | | | | | | |
| granulata | | | | | | | | * | * | | * |
| lata | | | | | | | * | | | | |
| lepis | | | * | | | | | | | | |
| Lewisii | | | | | * | | | | | * | |
| longissima | | | | * | | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lingula obtusa | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| ovata | ... | ... | ... | ... | * | * | * | ... | * | * | |
| parallela | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| plumbea | ... | ... | * | ... | ... | ... | * | * | | | |
| Ramsayi | ... | ... | ... | ... | ... | ... | ... | * | | | |
| striata | ... | ... | ... | ... | ... | ... | * | | | | |
| tenuigranulata | ... | ... | ... | * | * | | | | | | |
| Obolus Davidsoni | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| transversus | ... | ... | ... | * | * | * | * | * | * | | |
| Orthis Actoniæ | ... | ... | ... | * | * | ... | ... | * | * | | |
| æquivalvis | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| alata | ... | ... | ... | ... | ... | ... | ... | * | | | |
| alternata | ... | ... | * | * | * | ... | ... | * | * | | |
| biforata | * | * | * | * | * | * | ... | ... | * | * | |
| biloba | ... | ... | ... | * | * | * | * | ... | * | ... | * |
| Bouchardii | ... | ... | ... | ... | ... | ... | ... | * | * | | |
| calligramma | * | * | * | * | * | * | ... | ... | * | *? | |
| confinis † | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| costata | ... | ... | ... | * | | | | | | | |
| crispa | ... | ... | ... | * | * | * | * | ... | * | | |
| Davidsoni | ... | ... | * | * | * | * | ... | ... | * | * | |
| elegantula | * | * | * | * | * | * | * | *? | * | * | * |
| var. orbicularis | ... | ... | ... | ... | * | * | ... | ... | ... | * | |
| fallax † | ... | * | | | | | | | | | |
| flabellulum | * | * | * | * | * | * | | | | | |
| Hirnantensis | ... | ... | * | * | ... | ... | ... | ... | ... | * | |
| hybrida | ... | ... | ... | ... | ... | * | ... | ... | * | * | |
| insularis | ... | ... | ... | ... | ... | * | * | * | * | * | * |
| intercostata † | ... | ... | ... | ... | * | | | | | | |
| interplicata † | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * |
| lata | ... | ... | ... | ... | ... | * | * | | | | |
| Lewisii | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| lunata | ... | ... | ... | * | * | * | * | | | | |
| porcata | ... | ... | ... | * | * | * | ... | ... | * | * | |
| productoides † | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * |
| radians | ... | ... | ... | * | | | | | | | |
| remota | ... | ... | ... | ... | ... | ... | ... | * | | | |
| reversa | ... | ... | ... | * | * | | | | | | |
| rustica | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| sagittifera | ... | ... | ... | * | * | | | | | | |
| semicircularis | ... | ... | ... | ... | * | | | | | | |
| simplex | ... | ... | ... | * | * | * | ... | ... | ... | * | |
| spiriferoides | * | * | * | * | * | * | ... | * | * | * | |
| striatula | ... | ... | ... | ... | ... | ... | ... | * | * | * | |
| testudinaria | ... | * | * | * | * | ... | ... | ... | ... | *? | |
| triangularis | ... | ... | ... | ... | * | | | | | | |
| tricenaria † | ... | ... | ... | ... | ... | * | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Orthis turgida | | | | * | * | * | | | | | |
| unguis | | | | * | | | | | | | |
| vespertilio | | | | * | * | | | | | | |
| Orthisina ascendens | | | | | | * | * | | | | |
| Scotica † | | | | | | | | | * | * | |
| Pentamerus galeatus | | | | | | * | * | | * | * | |
| globosus | | | | * | | | | | | | |
| Knightii | | | | | | | | | * | * | * |
| lævis | * | * | * | * | * | | | | | | |
| lens | * | * | * | * | * | * | | | | | |
| linguifer | | | | | | | | | * | * | |
| liratus | | | * | * | * | | | | | | |
| oblongus | * | * | * | * | * | | | | | | |
| undatus | | | * | * | * | * | | | | | |
| Porambonites intercedens † | | | | | | | | | | * | |
| Retzia Barrandei | | | | | | | | | | * | |
| Baylei | | | | | | | | | * | * | |
| Bouchardii | | | | | | | | | | * | |
| cuneata | | | * | * | * | * | | | * | * | |
| Salteri | | | | | | | | | * | * | |
| Rhynchonella angustifrons | | | | * | * | | | | | | |
| borealis | | | | * | * | * | | | * | * | |
| brevirostrum | | | | | | * | | | * | * | |
| compressa | | | | | | | | | | * | |
| crebricosta | | | | | | | | | * | * | |
| crispata | | | | | | | | | * | * | |
| Davidsoni | | | | | | | | | | * | |
| decemplicata | * | * | * | * | * | | | | | | |
| deflexa | | | | | | | | | * | * | |
| depressa | | | | | | | | | * | * | |
| didyma | | | | * | * | * | * | | * | * | |
| furcata | * | * | * | * | | | | | | | |
| Grayii | | | | | | | | * | * | * | |
| interplicata | | | | | | | | | * | * | |
| Lewisii | | | | * | * | | | | * | * | |
| nasuta † | | | | | | | | | * | | |
| navicula | | | | * | * | * | * | | * | | |
| neglecta | | | | * | | | | | | | |
| nitida | | | | | | | | | | * | |
| nucula | * | * | * | * | * | * | * | | * | * | * |
| obtusiplicata | * | | | | | | | | | | |
| pentagona | | | | | | | | | | * | |
| pusilla | | | | * | | | | | | | |
| rotunda | | | | | | * | | | | * | |
| serrata | | * | * | * | | | | | | | |
| sexcostata | | * | | | | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rhynchonella sphærica | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |
| sphæroidalis | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Stricklandi | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| subundata | ... | ... | ... | * | | | | | | | |
| tripartita | ... | ... | ... | * | | | | | | | |
| upsilon | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| Wilsoni | ... | ... | ... | ... | ... | * | ... | ... | ... | * | |
| Siphonotreta Anglica | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | |
| nucula | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| Spirifer crispus | ... | ... | ... | ... | ... | * | ... | ... | * | * | * |
| elevatus | ... | ... | ... | * | * | * | ... | ... | * | * | * |
| ? pisum | ... | ... | ... | ... | ... | * | ... | ... | ... | * | |
| plicatellus | ... | ... | ... | * | * | * | ... | ... | * | * | |
| trapezoidalis | ... | ... | ... | * | * | * | * | ... | * | * | |
| Strophomena alternata | ... | ... | ... | * | * | * | ... | ... | * | * | * |
| bipartita | ... | ... | ... | ... | * | * | * | ... | * | | |
| antiquata | ... | ... | ... | * | * | * | * | ... | * | * | * |
| applanata | ... | ... | ... | * | * | * | * | | | | |
| arenacea | ... | ... | * | * | * | | | | | | |
| complanata | ... | ... | ... | * | | | | | | | |
| compressa | ... | * | * | * | * | | | | | | |
| concentrica | ... | * | * | * | * | | | | | | |
| corrugata † | ... | ... | ... | * | * | * | * | ... | ... | * | |
| deltoidea | ... | ... | ... | * | * | * | ... | ... | ... | * | |
| depressa | ... | ... | ... | ... | ... | ... | ... | ... | * | * | * |
| euglypha | ... | ... | ... | ... | *? | * | ... | ... | * | * | * |
| expansa | ... | ... | * | * | * | | | | | | |
| filosa | ... | ... | ... | ... | * | * | ... | ... | * | * | |
| funiculata | ... | ... | ... | * | * | * | * | ... | * | * | |
| grandis | ... | ... | * | * | * | | | | | | |
| imbrex | ... | ... | ... | ... | ... | ... | ... | ... | * | * | * |
| Ouralensis | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * |
| pecten | ... | ... | * | * | * | * | | | | | |
| simulans | ... | ... | ... | ... | ... | * | ... | ... | * | | |
| tenuistriata | ... | ... | ... | * | * | * | ... | ... | ... | * | |
| undata | ... | ... | ... | * | * | ... | ... | ... | ... | * | |
| Terebratula? læviuscula | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| Trematis punctata | ... | ... | ... | * | | | | | | | |
| **MONOMYARIA.** | | | | | | | | | | | |
| Ambonychia acuticosta | ... | ... | ... | ... | * | ... | * | | | | |
| carinata | ... | ... | ... | * | | | | | | | |
| gryphus † | ... | ... | ... | ... | * | | | | | | |
| transversa † | ... | ... | ... | ... | * | | | | | | |
| trigona † | ... | ... | ... | | * | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambonychia triton | | | | | | | | | | * | |
| undata † | | | | | * | | | | | | |
| Avicula ampliata | | | | | | * | * | | | | |
| antiqua ? | | | * | | | | | | | | |
| bullata † | | | * | * | | | | | | | |
| Danbyi | | | * | | | | | | | | |
| mira | | | | | | | | | * | * | |
| panopææformis † | | | | | | * | | | | | |
| Pterinæa asperula | | | | | | * | | | | | |
| Boydii | | | * | | | | | | | | |
| demissa | | | * | * | | | | | | | |
| fimbriata | | | | | | * | | | | | |
| hians | | | | | | | | | | * | |
| lineata | | | * | * | | | | | | | |
| lineatula | | | | | | * | * | | | | |
| megaloba | | | * | | | | | | | | |
| orbicularis † | | | | | | * | | | | | |
| planulata | | | | * | * | * | * | | * | * | |
| pleuroptera | | | *? | * | * | * | | | | | |
| rectangularis | | | * | | | | | | | | |
| retroflexa | | * | * | * | * | * | | | * | * | |
| Sowerbyi | | | | | | | | | * | | |
| subfalcata | | | * | | | | | | | | |
| sublævis † | | | | * | | | | | | | |
| tenuistriata | | | | * | * | * | * | | | | |
| DIMYARIA. | | | | | | | | | | | |
| Anodontopsis angustifrons | | | * | | | | | | | | |
| bulla | | | * | * | | | | | | | |
| lævis | | | * | | | | | | | | |
| perovalis | | | | * | * | | | | | | |
| quadratus | | | | | * | | | | | | |
| securiformis | | | * | | | | | | | | |
| Arca ? primitiva | | | | * | | | | | | | |
| Cardiola fibrosa | | | | | | * | * | | | | |
| interrupta | | | | | | * | * | | | | |
| semirugata † | | | | | | * | | | | | |
| (Ambonychia) striata | | | | | | * | | * | * | | |
| Cleidophorus ovalis | | | | * | * | | | | | | |
| planulatus | | | | | * | | | | | | |
| Ctenodonta ambigua | | | | | * | | | | | | |
| Anglica (ovalis) | | | | * | * | * | * | | | | |
| deltoidea | | | | * | * | | | | | | |
| dissimilis † | | | | | * | | | | | | |
| Eastnori | | * | * | * | * | | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ctenodonta Edmondiformis | | | | * | * | | | | | | |
| lævis | | | | | | | | * | | | |
| lingualis | | | | * | * | | | | | | |
| obliqua | | | | | * | * | | | | | |
| poststriata | | | | | * | | | | | | |
| quadrata † | | | | * | | | | | | | |
| radiata | | | | | * | | | | | | |
| regularis † | | | | | * | | | | | | |
| rhomboidea | | | | * | * | | | | | | |
| scitula | | | | | | | * | | | | |
| semitruncata † | | | | | * | | | | | | |
| subacuta | | | | | * | | | | | | |
| subæqualis | | * | * | * | | | | | | | |
| subcylindrica † | | | | * | | | | | | | |
| transversa † | | | | | * | * | | | | | |
| varicosa | | | | * | * | * | * | | | | |
| Cucullella Anglica | | | | | * | | | | | | |
| antiqua | | | * | * | * | | | | | | |
| Cawdori | | | | | * | | | | | | |
| coarctata | | | | | * | | | | | | |
| ovata | | | * | * | * | * | | | | | |
| Dolabra? elliptica | | | * | | | | | | | | |
| obtusa | | | * | | | | | | | | |
| Goniophora cymbæformis | | | * | * | * | * | * | | | | |
| Grammysia cingulata | | | * | * | * | | | | | * | |
| extrasulcata | | * | * | | | | | | | | |
| rotundata † | | | * | | | | | | | | |
| triangulata | | * | * | | | | | | | | |
| Lyrodesma cuneata | | | | | * | | | | | | |
| plana (M'Coy) | | | | | | * | | | | | |
| Megalomus, sp. | | | | * | | | | | | | |
| Modiolopsis antiqua | | | | | | * | * | | * | | |
| complanata | | | | | * | | | | | | |
| expansa † | | | | | * | | | | | | |
| gradata | | | | | | * | * | | | | |
| inflata | | | | | | * | | | | | |
| sp. (modiolaris, M'Coy.) | | | | * | * | | | | | | |
| Nerei † | | | | | * | | | | | | |
| obliqua | | | | * | * | | | | | | |
| orbicularis | | | | * | * | | | | | | |
| perovalis | | | | | | * | | | * | | |
| platyphylla | | | * | | | | | | | | |
| postlineata | | | | | * | * | | | | | |
| quadrata | | | | | | * | * | | | | |
| securiformis | | | | | * | | | | | | |
| Mytilus Chemungensis | | | | * | * | * | | | | | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mytilus cinctus † | | | | | | * | | | | | |
| exasperatus | | | | | * | * | | | | | |
| mytilimeris | | | | * | * | * | | | * | * | * |
| unguiculatus | | | * | * | | | | | | | |
| Orthonota amygdalina | | | | | * | * | * | | | | |
| angulifera | | | | | | * | | | | | |
| globulosa † | | | * | | | | | | | | |
| impressa | | | | | | * | * | | | | |
| nasuta † | | | | * | | | | | | | |
| prora † | | | * | | | | | | | | |
| rigida | | | | | | * | * | | | | |
| rotundata † | | | | | | | * | | | | |
| semisulcata | | | | | | * | | | * | | |
| solenoides | | | | | | * | * | | | | |
| truncata | | | * | | | | | | | | |
| undata | | | | | | | * | | | | |
| Pleurorhyncus æquicostatus | | | | | | | | | | * | |
| dipterus † | | | | | | | | | * | * | |
| pristis † | | | | | | | * | | | | |
| **Gasteropoda.** | | | | | | | | | | | |
| Acroculia euomphaloides | | | | | | | | | | * | |
| Haliotis | | | | * | * | | | | * | * | |
| prototypa | | | | | | | | | | * | |
| Chiton Grayanus | | | | | | | | | * | | |
| Griffithii † | | | | | | | | | * | | |
| Wrightianus | | | | | | | | | * | | |
| Cyclonema corallii | | | | | * | * | * | | | | |
| crebristria | | | * | * | * | * | * | | * | * | |
| octavia | | | | | | * | * | | | | |
| quadristriata | | | | * | | | | | | | |
| rupestris † | | | | | | | | | | * | * |
| sulcifera | | | | | | | | | | * | * |
| undifera | | | | | | | | | | * | |
| ventricosa | | | | * | | | | | | | |
| Euomphalus alatus | | | | | | * | | | * | * | |
| carinatus | | | | | | | | | | * | |
| centrifugus | | | | | | | | | * | * | |
| Corndensis | | * | | | | | | | | | |
| discors | | | | | | | | | | * | |
| funatus | | | | * | * | * | * | | * | * | * |
| lautus † | | | | | | * | * | | | | |
| prænuntius | | | | * | | | | | | | |
| rugosus | | | | | | | | | | * | * |
| sculptus | | | | *? | | | | | | * | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Holopæa concinna † | | | | | | | | | * | * | |
| striatella | | | | | * | * | | | * | * | |
| Holopella cancellata | * | * | * | * | * | | | | | | |
| conica | | * | * | * | * | | | | | | |
| gracilior | | | | | | * | * | | | | |
| gregaria | | * | * | * | * | | | | | | |
| intermedia | | * | * | | | | | | | | |
| monile | | | | * | | | | | | | |
| obsoleta | * | * | * | * | | | | | | | |
| plana † | | | | * | | | | | | | |
| tenuicincta † | | | | * | | | | | | | |
| Loxonema elegans | | | | | | | | | * | | |
| sinuosa | | | | | | | | | | * | |
| Macrocheilus elongatus † | | | | | * | * | | | | | |
| fusiformis | * | | * | | | | | | | | |
| Murchisonia angulata | * | * | * | * | | | | | | | |
| angustata † | | | | | | | | | | * | |
| articulata | | | * | * | | * | * | | | | |
| balteata | | | | | | | | | | * | |
| bicincta, M'Coy † | | | | | | | | | | | * |
| cancellatula | | | | * | | | | | | | |
| cingulata | | | | | | | | | | * | |
| corallii | | | | | * | * | | | | | |
| gyrogonia | | | | * | * | | | | | | |
| inflata † | | | | * | | | | | | | |
| Lloydii | | | | | * | * | * | | | * | |
| obscura † | | | | | * | | | | | | |
| Pryceæ | * | * | * | * | | | | | | | |
| pulchra | | | | * | * | | | | | | |
| simplex | | | | * | | | * | | | * | |
| subrotundata † | | | | | * | | | | | | |
| sulcata † | | | | | | * | | | | | |
| torquata † | | * | | | | | | | | | |
| turrita † | | | | | * | * | | | | | |
| Natica parva | | | | | | * | * | | | | |
| Ophileta compacta | | * | | | | | | | | | |
| macromphala † | | | | | | | | | | * | |
| Patella Saturni | | | | | * | | | | | | |
| Platyschisma helicites | * | * | * | * | * | * | * | | | | |
| Williamsi | | | * | * | * | | | | | | |
| Pleurotomaria crenulata | | | * | | | | | | | | |
| fissicarina | | | | * | | | | | | | |
| trochiformis † | | | | | | | * | | | | |
| undata | | | | | | | * | | * | * | |
| sp. (trochiformis, M'Coy) † | | | | | | * | | | | | |
| Raphistoma æqualis | | | | | | | | | * | * | |

Table XIX. (*continued*).

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Raphistoma elliptica † | | | | | | | * | | | | |
| lenticularis | | | * | * | * | * | | | | | |
| Ribeiria complanata | | | | | * | | | | | | |
| Trochonema latifasciata † | | | | | * | | | | | | |
| lyrata | | | | | | * | | | | | |
| tricincta † | | | | * | | | | | | | |
| triporcata | | | | * | | * | | | | | |
| trochleata † | | | | * | | | | | | | |
| Trochus ? cælatulus | | | | | | | | | | * | |
| Moorei † | | | | * | | | | | | | |
| multitorquatus † | | | | * | | | | | | | |
| Turbo ? cirrhosus | | | | | | | | | | * | |
| tritorquatus † | | | * | * | | | | | | | |
| HETEROPODA. | | | | | | | | | | | |
| Bellerophon acutus | | | | | * | * | * | | | | |
| alatus † | | | | | * | | | | | | |
| bilobatus | | * | * | * | * | * | * | * | * | | |
| carinatus | | | * | * | * | * | | | | | |
| dilatatus | | | * | * | * | * | * | | * | * | |
| expansus | | | * | * | * | * | * | | | | |
| Murchisoni | | | * | * | | | | | | | |
| nodosus | | | * | * | * | | | | | | |
| obtectus | | | | * | | | | | | | |
| perturbatus | | * | | | | | | * | | | |
| subdecussatus | | | *? | * | * | | | | | | |
| sulcatinus | | | | | * | | | | | | |
| Wenlockensis | | | | | | * | * | | * | * | |
| PTEROPODA. | | | | | | | | | | | |
| Conularia elongata † | | | | | | | * | | | | |
| Sowerbyi | | | | * | * | * | * | | * | * | |
| subtilis † | | | * | | | | | | | | |
| Ecculiomphalus Bucklandi | | | | | | | * | | | | |
| lævis | | | | | | * | * | | * | | |
| Scoticus | | | | * | | | | | | * | |
| Maclurea Logani | | | | | | | | | | * | |
| magna ? † | | | | | | | | | | * | |
| Peachii † | | | | | | | | | | * | |
| Pterotheca corrugata | | | | | * | * | | | | | |
| transversa † | | | | | * | | | | | | |
| sp. | | | * | | | | | | | | |
| Theca anceps | | | | | | | * | | | | |
| Forbesii | | | * | * | * | * | * | | | | |

Table XIX. *(continued)*.

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.). | 5 Argill. Sandstone. | 6 Calcareo-argil. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Theca reversa | | * | | | | * | | | | * | |
| simplex | | | | | | * | | | | | |
| triangularis | | | | | * | * | | | | | |
| vaginula | | | | | | * | | | | | |
| CEPHALOPODA. | | | | | | | | | | | |
| Ascoceras Barrandii | | | | | | * | * | | | | |
| Cyrtoceras approximatum | | | * | | | | | | | | |
| inæquiseptum † | | | | | * | | | | | | |
| multicameratum ? † | | | | | | | | | | * | |
| Lituites anguiformis | | | | | | | | | | * | |
| articulatus | | | | | | | * | | | | |
| Biddulphii | | | | | | | | | | * | |
| cornu-arietis | | | | | * | * | | | * | * | |
| giganteus | | | | | | | | | * | * | |
| Hibernicus † | | | | | | | | | | * | * |
| planorbiformis | | | | * | | | | | | | |
| tortuosus | | | | | | * | | | | * | |
| undosus | | * | | | | | | | | | |
| Orthoceras angulatum | | | | * | * | * | * | | * | * | |
| annulatum | | | | * | * | * | * | | * | * | |
| arcuoliratum † | | | | | | | | | | * | |
| attenuatum | | | | | | | | | | * | |
| Avelinii | | | | | | | * | | | | |
| baculiforme † | | | * | | | | | | | | |
| Barrandii | | | * | | | | | | | | |
| bilineatum † | | | | * | * | | | | | | |
| breviconicum † | | | | | * | | | | | | |
| Brongniartii † | | | | * | | | | | | | |
| bullatum | | | * | * | * | * | | | | | |
| canaliculatum | | | | | | | | | | * | |
| centrale † | | | | * | | | | | | | |
| coralliforme † | | | | * | * | | | | | | |
| dimidiatum | | | * | | | * | * | | | | |
| distans | | | | | | | | | | * | |
| encrinale | | | | | | | * | | | | |
| elongatocinctum | | | | | | * | * | *? | | | |
| excentricum | | | | | | | | | | * | |
| filosum | | | | | * | * | * | | | | |
| fimbriatum | | | | | | | | | | * | |
| gregarium | | | | | | | | | | * | |
| ibex | | | | | * | * | * | | * | * | |
| imbricatum | | | | | * | * | | | * | | |
| laqueatum † | | | | | | * | * | | | | |
| Ludense | | | | | | * | * | | | | |

Table XIX. *(continued)*.

| Genera and Species. | 1 Siliceous Conglom. | 2 Siliceous Grit. | 3 Siliceous Sandst. | 4 Calcareous Sandst. (Earthy Limest.) | 5 Argill. Sandstone. | 6 Calcareo-argill. Sh. | 7 Mudstone. | 8 Carbon. Shale. | 9 Argillo-calcar. Sh. | 10 Argill. Limestone. | 11 Limestone. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Orthoceras Maclareni † | | | | | | | * | | | | |
| Marloense | | | | | | * | | | | | |
| Mocktreense | | | | | | | | | | * | |
| nummularium | | | | * | | | | | | | |
| perannulatum † | | | | | * | | | | | | |
| perelegans | | | | * | * | * | * | | * | | |
| politum † | | | | | | | * | | | | |
| Pomeroense | | | | | * | | | | | | |
| primævum | | | | * | * | * | * | * | | | |
| subgregarium† | | | | * | | | | | | | |
| subundulatum | | | * | * | * | * | * | * | * | | |
| tenuiannulatum | | | * | | | | * | | | | |
| tenuicinctum | | | | | * | * | | | | | |
| tenuistriatum | | | | * | * | | | | | | |
| textile | | | | * | | | | | | | |
| torquatum † | | | * | | | | | | | | |
| tracheale | | | * | * | * | | | | | | |
| vagans | | | | | | | | | | * | * |
| vaginatum † | | | * | | | | | | | | |
| ventricosum | | | | | | | * | * | | | |
| Oncoceras ? sp. | | | | | | | | | | * | |
| Phragmoceras arcuatum | | | | | | * | * | | | | |
| compressum | | | | * | * | * | * | | | | |
| intermedium | | | | | | * | | | | | |
| nautileum | | | | | * | * | * | | | | |
| pyriforme | | | | | | * | * | | * | * | |
| ventricosum | | | | | | | | | * | * | |
| Poterioceras approximatum | | | | * | | | | | | | |
| Tretoceras bisiphonatum | | | | | * | | | | | | |
| semipartitum | | | | * | | | | | | | |
| Pisces. | | | | | | | | | | | |
| Auchenaspis Salteri | | | | | | * | | | | | |
| ? ornatus | | | | | | * | | | | | |
| Cephalaspis Murchisoni | | | * | * | | | | | | | |
| Onchus Murchisoni | * | * | | | | | | | | | |
| tenuistriatus | * | * | | | | | | | | | |
| sp. | | * | | | | * | | | | | |
| Plectrodus mirabilis | * | | | | | *? | | | | | |
| pustuliferus | * | | | | | | | | | | |
| Pteraspis Banksii | | | * | * | * | | | | | | |
| truncatus | | * | | * | | | | | | | |
| Ludensis | | | | | | * | | | | | |
| Sphagodus | * | | | | | | | | | | |

## 1. *On the Relations of the different parts of the* Old Red Sandstone *in which* Organic Remains *have recently been discovered, in the* Counties *of* Moray, Nairn, Banff, *and* Inverness. By J. G. Malcolmson, M.D., F.G.S.

[Read June 5th, 1839.]

(Plate XI.)

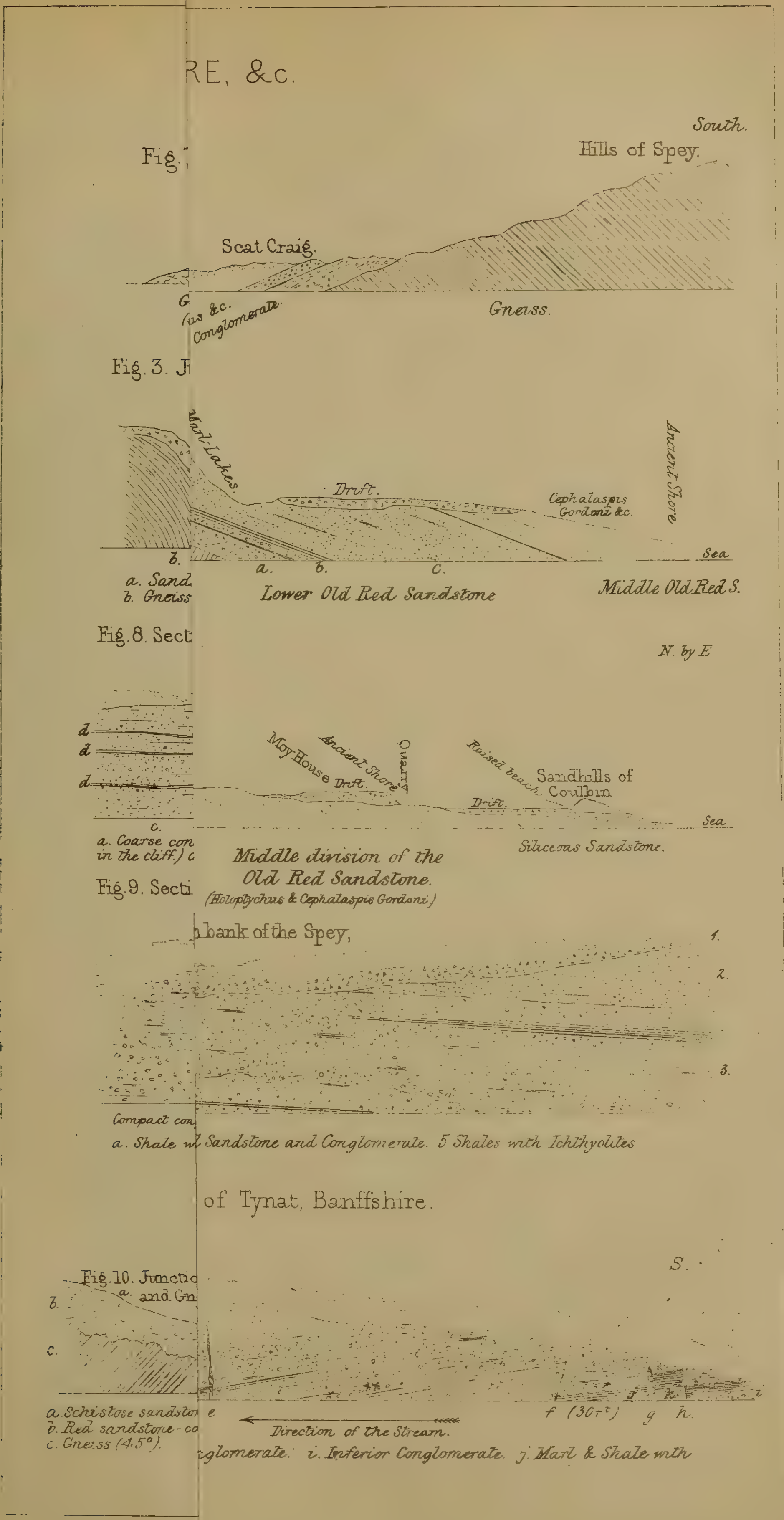
[This communication was received June 4, 1839; read June 5, 1839; referred November 6, 1839; and reported upon favourably May 27, 1840; but the determination to print the paper was deferred by the Council until Prof. Agassiz should have supplied the description of the fossil fishes which are mentioned in it, and which had been sent to the Continent for examination. The Memoir, prepared to a great extent for press, with its illustrative sections arranged for engraving, thus remained unpublished. In May 1844, the death of Dr. Malcolmson was announced; and in June and November 1844, inquiry was made respecting the Memoir, which, apparently, still waited for the description of the specimens. About this time the 'Monographie des Poissons Fossiles du Vieux Grès Rouge' was published, containing an account of the fossil fishes referred to in the Memoir; but those who had been interested in the determination of Dr. Malcolmson's specimens, and who had apparently undertaken to finish the preparation of portions of the Memoir, had long before left England,—Sir Roderick Murchison for Russia and the Ural, in 1840,—Dr. Falconer for India. On Dr. Falconer's return he made inquiries for the paper, but not in the right direction; and both Sir Roderick Murchison and Dr. Falconer came to the conclusion that it was lost. When Sir R. Murchison was occupied, in the winter of 1858, with his description of the Elgin Sandstones, and after he had received a communication from the Rev. G. Gordon respecting Dr. Malcolmson's MSS., supposed by him to be lost, his attention was drawn, at the apartments of the Geological Society, to Dr. Malcolmson's MS. sections; and, on inquiry, he ascertained, to his surprise, that Dr. Malcolmson's MS. Memoir was not missing, but in its place in the Society's archives.

The Rev. G. Gordon had informed Sir R. Murchison that a paper by him, on the geology of the northern part of Moray, would appear in the Edinburgh New Philosophical Journal for January 1859, and that this paper would comprise a large portion of the original Memoir by Malcolmson (of which Mr. Gordon possesses a copy), together with some observations on the non-publication of the Memoir referred to. Sir Roderick had just time, after learning that the paper and its sections were in good preservation, to communicate to Mr. Gordon the explanatory note which appears at pages 59* and 60* of the Journal above referred to; and he immediately drew the attention of the Council of the Geological Society to the delay that had occurred in the publication of Dr. Malcolmson's Memoir and Sections.

On January 19 and Feb. 23, 1859, the Council took into consideration the publication of Dr. Malcolmson's Memoir, and came to the resolution, "That all the details of that paper which are not given in Mr. Lonsdale's abstract (Proceed. Geol. Soc. vol. iii. p. 141) or in the recent paper of Mr. Gordon, referred to above, be printed in full, together with a lithograph plate of sections in illustration of the same."

Plate XI. contains all the sections that accompanied the MS. Memoir. One coloured drawing of a fish, too obscure for determination, a pencil-sketch of a vegetable fragment resembling those figured by Mr. Salter in Quart. Journ. Geol. Soc. vol. xiv. pl. 5, figs. 3–5, and a topographical map are the remaining illustrations.

Since the date of this Memoir, considerable modifications have been made in the nomenclature of the several members of the Old Red Sandstone, giving rise to a systematic arrangement different from that here advanced by Dr. Malcolm-



RE, &c.
Fig. 7
South.
Hills of Spey.
Scat Craig.
G
(us &c.
Conglomerate
Gneiss.
Fig. 3. J
Marl Lakes.
Drift.
Cephalaspis Gordoni &c.
Ancient Shore
Sea
b.
a.
b.
c.
a. Sand.
b. Gneiss
Lower Old Red Sandstone
Middle Old Red S.
Fig. 8. Sect
N. by E.
d
d
d
Moy House
Drift.
Ancient Shore
Quarry
Raised beach
Sandhills of Coulbin
Drift.
Sea
c.
a. Coarse con
in the cliff.) c
Middle division of the Old Red Sandstone.
(Holoptychus & Cephalaspis Gordoni.)
Siliceous Sandstone.
Fig. 9. Secti
h bank of the Spey,
1.
2.
3.
Compact con
a. Shale w Sandstone and Conglomerate. 5 Shales with Ichthyolites
of Tynat, Banffshire.
S.
Fig. 10. Junctio
a. and Gn
b.
c.
j
k
l
a. Schistose sandsto e
b. Red sandstone-co
c. Gneiss (45°).
Direction of the Stream.
f (30ft) g h.
nglomerate. i. Inferior Conglomerate. j. Marl & Shale with

# SECTIONS OF THE OLD RED SANDSTONE OF MORAYSHIRE, &c.

By Dr. Malcolmson, F.G.S. (1839)

Fig. 1. Junction of Granite & Gneiss, N. of Coulmony

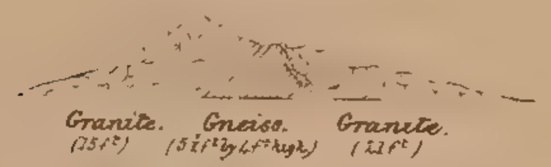



Fig 2

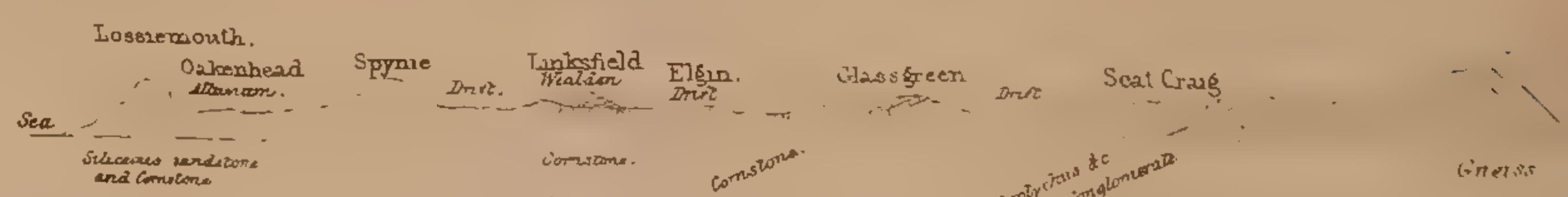
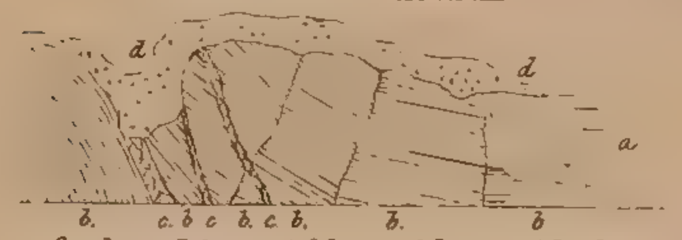
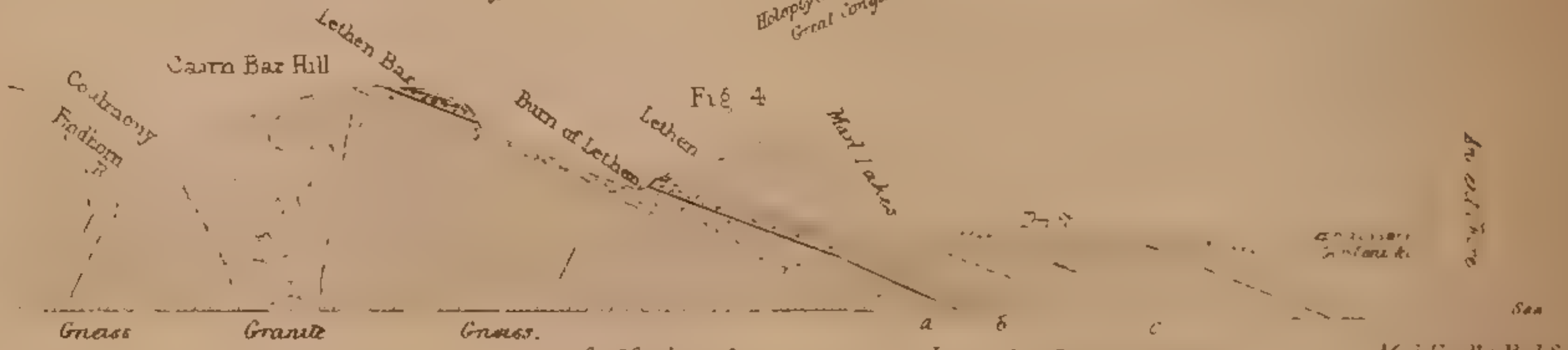



Fig. 3. Junction of the Sandstone with the Gneiss at Sluy on the River Findhorn.



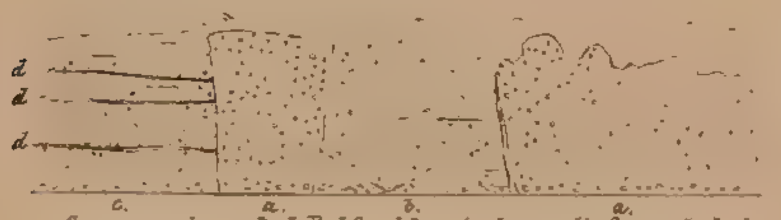

a. Sandstone, Inferior part of the central division of the Old Red S.
b. Gneiss. c. Granite. d. Soil & drift.

Fig 4



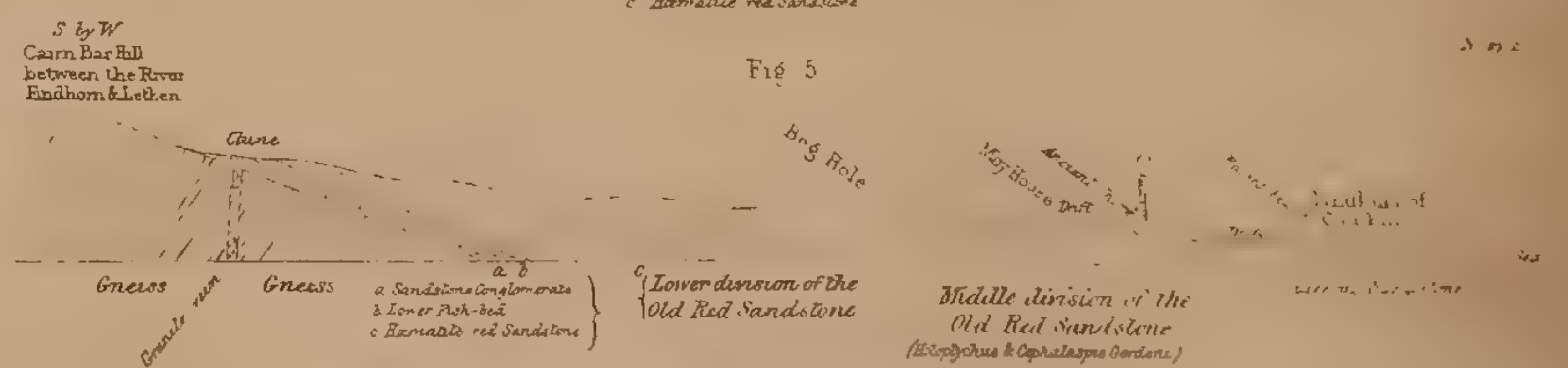

a. Great Conglomerate
b. Lower Fish-beds
c. Haematite red Sandstone

Fig. 8. Section opposite the Fish-beds, Burn of Tynat. (Lower down the Stream.)




a. Coarse conglomerate. b. Red Sandstone (perhaps a slip from rocks higher in the cliff) c. Sandstone-conglomerate. d. Shale with Ichthyolites

Fig 5




a. Sandstone Conglomerate
b. Lower Fish-bed
c. Haematite red Sandstone

Lower division of the Old Red Sandstone

Middle division of the Old Red Sandstone (Holoptychius & Cephalaspis Gordoni)

Fig. 9. Section opposite the Fish-beds, Burn of Tynat. (Higher up the Stream.)


Compact conglomerate (Probably a slip from above)
a. Shale with nodules. b. Thin-bedded sandstones

Fig. 6. Section of the Fish-beds at Dipple, on the north bank of the Spey, near Fochabers, Morayshire.


1. Gravel 2. Red Sandstones of the Bridge of Spey 3 Coarse conglomerate 4. Red Sandstone and Conglomerate 5 Shales with Ichthyolites

Fig. 11. Section in the Burn of Aberdour.


Fig. 10. Junction of Sandstone and Gneiss, Burn of Buckie, Banffshire

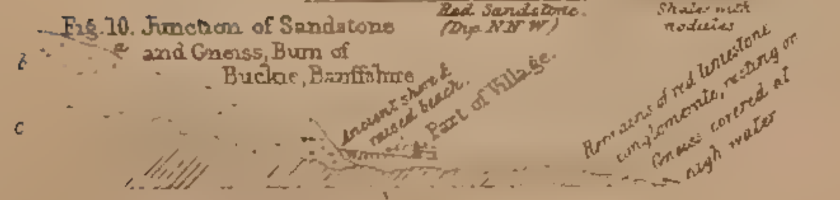



Fig. 7. Section of the Fish-beds, Burn of Tynat, Banffshire.


a. Principal Fish-bed. *Large Dipterus in Sandstone .. Scales in conglomerate ... nodules. h. Lower Fish-bed, 9 ft. thick

son; the reader is therefore referred to the two next following Memoirs for the plan and details of the classification at present adopted.—Ed. Q. J. G. S.]

Contents.



*Introduction.*—The object* of the following paper is to show that the vast series of rocks in the North of Scotland included under the name of the Old Red Sandstone system† may be separated into several great subdivisions, two of which are characterized by numerous organic remains of very peculiar and distinct forms; and to identify with these subformations, as exhibited along the southern shores of the Moray Frith, the vast fossiliferous strata belonging to the same system in Caithness and the Orkneys, and in the South of Scotland and in England. The following tabular statement embraces a general view of these divisions as exhibited in the counties of Moray and Nairn, and in the adjoining parts of Banff and Inverness, in the ascending series, which I have adopted on the present occasion to avoid the confusion that might arise from commencing the enumeration from the broken and denuded portions of the comparatively ill-ascertained strata forming the highest rocks of the series.

A. Elevated and contorted gneiss traversed by granite- and porphyry-dykes.

B. Old Red Sandstone.

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| 1st or Lower division: subdivided into— *a.* "The Great Conglomerate;" consisting of vast beds of a very coarse conglomerate with bands of red sandstone. | *a.* W. coast of Scotland and southern side of the Grampians. |
| *b.* Red Sandstones, shales with calcareous nodules, and limestones, abounding in remains of fishes and plants. | *b.* Orkney and Caithness; bituminous flagstones with fishes and plants, galena, blende, and copper. Tile-stones of England. |
| *c.* Argillo-calcareous Sandstones and Conglomerates, mostly of a deep-red colour, sometimes black or white. | *c.* White and yellow Sandstones of Orkney and Caithness, and of Cromarty and Easter Ross. |
| 2. Central division or Cornstone series. Sandstones, calciferous conglomerates, marls, &c., abounding in remains of fishes, all different from those of No. 1, *b.* Contains beds of Cornstone ‡. | Clashbinnie in Perthshire. Herefordshire Cornstones. |

* [This introduction was added by the author subsequently, it appears, to the reading of the Memoir.—Ed. Q. J. G. S.]

† I here adopt the term "system" as first applied by Mr. Murchison to the Old Red Sandstone ('Silurian System,' p. 169).

‡ The upper beds at Nairn consist of a siliceous conglomerate with remains of fish. Some of the beds of this rock furnish one of the finest building-stones in Scotland.

| | |
|---|---|
| 3. Upper division. Fine, white, grey, and yellow siliceous sandstone and conglomerates, with cornstones containing galena, &c. | Quartzose Conglomerate of England. (See 'Silurian System,' vol. i. p. 171.) |

The general characters of the Old Red Sandstone rocks of Morayshire and the adjoining counties were long ago well described by Professor Sedgwick and Mr. Murchison *; and Dr. M'Culloch has laid down the general boundaries of the system with considerable accuracy. But in the absence of organic remains, it was impossible to compare the several parts of this vast system with those at a distance, or even with portions of the same rock in the district itself. It is therefore fortunate that these strata have proved to be very rich in fossils, distributed in beds which are laid open in magnificent natural sections, and which afford the means of tracing the several divisions of the system throughout the counties between the Grampian Mountains and the Moray Frith, and of instituting a comparison with those of other parts of the kingdom.

[The paper, as read before the Society, commences here; but the first paragraph of Mr. Lonsdale's Abstract (Proceed. Geol. Soc. vol. iii. p. 141) gives the chief matter of this portion of Dr. Malcolmson's Memoir.]

It is hoped that the discovery of a great variety of fossils, in various parts of the district referred to, in strata whose order of superposition can be ascertained (and one series of which is identical with those of Clashbinnie and other localities to the south of the Grampians, and the other with those of Caithness, Gamrie †, &c.), will assist in completing the history of those rocks which are developed on such a stupendous scale in the northern and central parts of Scotland. But, as one of the most important of these localities was discovered only on the 4th of last month [May, 1839], it is not to be expected that I should attempt more than to place before the Society the leading facts as yet ascertained regarding the relations of these strata,—that the inferences to which they lead, and the singular forms of many of the remains may be examined by those now engaged in tracing the history of these rocks in other localities ‡. I have also brought prominently forward the important fact, that great denudations were in progress during the whole period of the depo-

* Geol. Trans. 2 ser. vol. iii. p. 151, *note*.

† I cannot help thinking that some verbal error has found its way into the quotation from a letter of M. Agassiz, given in Mr. Murchison's 'Silurian System,' p. 599, where the genus *Holoptychus* is stated to occur at Gamrie so well preserved as to have enabled him to correct his ideas regarding the genus *Gyrolepis*. I have failed to discover any well-marked specimen that could be referred to the fish called after Mr. Noble, amongst the many I have seen from this locality. Fish with scales, having the character of this genus, however, occur at Gamrie, Cromarty, &c. It may be observed that in the passages quoted from M. Agassiz' letter, he does not mention Clashbinnie.

‡ With this view I propose presenting to the Museum such of the specimens as may be thought worthy of a place in the Society's collection, it being my wish, and that of the Rev. G. Gordon and Mr. Stables (my colleagues in the investigation), that as complete a series as possible should be deposited here, reserving the duplicates for the Elgin Museum and our own cabinets.

sition of the Old Red Sandstone, by which different superior members of the system were placed in contact with the inferior rocks; and, as this discovery first afforded a key to the arrangement of these strata, I shall describe them rather in the order in which the inquiry was prosecuted than in the more approved method of a consecutive descending series.

The district over which the fossils have been discovered extends from the village of Buckie, near Cullen, in Banffshire, to Culloden Moors, six miles south of Inverness, in the Lowlands of the counties of Moray and Nairn, and the neighbouring parts of Banff and Inverness, great part of which is occupied by conglomerates and sandstones belonging to the Old Red system. All the higher and southern parts of this tract consist of primary rocks, mostly gneiss, in many places traversed by numerous branching and inosculating veins of granite, for the most part composed of very large crystals of red felspar and grey quartz, with a few scales of mica; but occasionally different parts of these veins consist of a fine-grained grey granite, with a greater abundance of mica, and, like the others, derived from granitic masses underneath, apparently of the same age. At Park, two miles south of Nairn, at Dulsie Bridge on the Findhorn, and at Coulmony (Pl. XI. fig. 1), between that river and Lethen, porphyritic granite, like that of Aberdeen, is seen in mass, and the neighbouring gneiss is much broken up, interlaced with a network of granite, and considerable portions of the strata are entangled in the eruptive rock.

The gneiss usually forms lengthened ranges of low hills, having a general direction of S.W. and N.E., nearly parallel to the great Caledonian valley, with steep sides towards the S.E., and sloping off gently in the opposite direction. The course of all the streams flowing into the south side of the Moray Frith observes nearly the same direction; and up the valleys in which they flow, the several members of the sandstone-series extend to very different distances, resting on the lower slopes and wrapping round the south-eastern extremities of the hills. They also occur in insulated patches, and different parts of the series come into contact with the gneiss in contiguous valleys or along the same stream, showing that during the whole period of the deposition of the Old Red Sandstones of the Moray Frith very extensive denudations were taking place. The primary rocks have been exposed in different places within the sandstone districts; and spurs and transverse ridges often project from the principal ranges, cutting off the different parts of the secondary rocks from each other. The general direction of the primary strata is nearly E. and W., the dip being for the most part from 45° to 65° S.; but they are often vertical, and where much broken up by granite, as at some places on the Rivers Findhorn and Lossie, they are contorted, and dip in all directions and at all angles. On the other hand, the sandstones, wherever they have been observed in contact with the primary rocks, rest on the edges of the latter, and dip at an angle of from 8° to 12° in the opposite direction, or a little W. of N.,—the granite-veins terminating at the junction with the sandstones, and furnishing fragments to the inferior conglomerates.

*Inferior or Great Conglomerate.*

[The author's description of this conglomerate is printed in the Rev. Mr. Gordon's Memoir, *op. cit.* pp. 29, 30; the only material difference being that Dr. Malcolmson has corrected "Hill of Rait" into "Hill of Urchony, south of Nairn."]

*Fossiliferous Strata of the Central or Cornstone division of the Old Red Sandstone, which near Elgin rest directly on the great Conglomerate.* See Section, Pl. XI. fig. 2.—The bed of calciferous conglomerate and red marly sandstone of Scat-craig near Elgin, formerly described (Proceed. Geol. Soc. 15th April, 1838), rests directly on the great conglomerate. Many of the bones and scales have been waterworn previously to the consolidation of the rock. They consist of scales of the *Holoptychus Nobilissimus* and other fishes,—several kinds of teeth, some of them of great size,—jaws with teeth,—new genera and species of ichthyodorulites, &c. A few of them have been examined by M. Agassiz, and at his recommendation I have had accurate drawings made of as many distinct forms as I had access to, mostly the property of the Elgin Museum, and of Mr. Gordon, of Binnie, Mr. Martin, and Mr. P. Duff. The fossiliferous rock is visible for only a short distance, where the drift has been removed by a small stream,—the upper stratum consisting of a conglomerate composed of completely rolled pebbles of various primary rocks and a few angular fragments of sandstone, cemented by ferruginous sand and calc-spar. Fossils are rarely found in this stratum, which exactly resembles some beds on the Findhorn, which are also devoid of fossils. Although the country is much obscured by drift, the situation of this rock below the cornstone of Elgin, as inferred by Mr. Gordon from the dip and direction of the strata*, has since been fully confirmed by the discovery of the same fossils in the magnificent natural sections from the cornstone to the gneiss laid open by the Findhorn.

Resting on these Elgin cornstones, a series of very beautiful white and yellow siliceous sandstones occurs, associated with a very hard conglomerate composed of a paste of siliceous grains, throughout which many completely rounded pebbles of white quartz and a few of gneiss and granite are scattered. The strike of these beds can be traced from Quarrywood Hill, near Elgin, to Burgie, $3\frac{1}{2}$ miles east of Forres, where they rest, at an angle of 10° N., on the vertical edges of the gneiss, which is interlaced with veins of granite; and the projecting gneissic hill of Blervie cuts off these sandstones of the east of the county from those of the Findhorn and of Nairnshire. This siliceous conglomerate and sandstone, which here, as in parts of England and Wales, appears to form the upper division of the Old Red System†, extends over a considerable part of the North-eastern district of Moray, the great fertility of which principally depends on

* Geol. Proceedings, April 15, 1838, and Murchison's 'Silurian System,' p. 600.

† Murchison's 'Silurian System,' p. 168.

the rich alluvial soil *within the ancient coast-line*, that derived from this sandstone being, for the most part, very sterile. This portion of the system has suffered considerable disturbance, on the examination of which I cannot at present enter; it is, however, necessary to observe, that at several places within the limits assigned to these sandstones, and interposed between their strata, a limestone resembling the cornstones of Elgin and Cothall occurs, which is extensively worked at Inverugie. On the coast near Lossiemouth it is in great part composed of silica, much of which is finely crystallized. At both these places a great deal of galena (with which Mr. Gordon found specimens of blende) is disseminated through the rock, and is most probably of contemporaneous formation, although in one or two instances the ore is most abundant along the lines of fracture*. A shaft has recently been driven through the Inverugie limestone (which is 12 feet in thickness) into the white siliceous sandstone below, but no ore was found in the inferior rock.

*Section through the Sandstones of the Findhorn, showing the central division resting directly on the Gneiss.* (Pl. XI. fig. 3.)—I shall now proceed to describe the central or Cornstone series †, as it is displayed in the fine sections laid open by the River Findhorn, which, after a course of many miles through the wildest and most beautiful scenery, emerges from a deep chasm in the gneiss (the perpendicular sides of which exhibit innumerable ramifications of fine red granite-veins) into more open reaches confined by mural cliffs of sandstone. The discovery of numerous fossils in many of the strata interposed between the gneiss and the Cothall limestone, described by Professor Sedgwick and Mr. Murchison, will render it necessary to give some details in addition to the brief notice contained in the admirable memoir so often referred to ‡. The junction of the gneiss and sandstone on the left bank of the river, opposite Sluy (fig. 3), exhibits the gneiss-strata bent into an arched form and traversed by granite-veins, one of which crosses a vertical joint in the stratified rock, on the opposite sides of which the gneiss dips at different angles, and the vein itself is slightly displaced. There are three of these fissures, the second of which is a foot-and-a-half wide, filled with carbonate of lime, mostly in the state of calc-spar, and mixed with green-earth, and many of the specimens have the appearance of the finer parts of the cornstones. This vein seems to have been filled from below; the gneiss near it is fractured by the granite, in several places brecciated, and altered into a ferruginous imperfectly laminated rock, not very easily distinguished from some varieties of trap; minute ramifications of calc-spar also are diffused through its most solid parts.

* See Weaver on the geological relations of the South of Ireland (Geol. Trans. vol. v. p. 60). The relations of these rocks cannot, however, be considered as having been sufficiently determined.

† From the occurrence of cornstone in other parts of the system, I would venture to suggest that it should not be used as a general term to distinguish one part of the system from another.

‡ Geol. Trans. 2 ser. vol. iii. p. 150.

Against the third fissure the secondary strata abut for a height of 20 feet, the upper part being covered by the disintegrated rock.

[The Rev. Mr. Gordon has given the author's subsequent description of the conglomerate and other beds of this division of the series, at pp. 31–33 of his Memoir.]

*Fossils of the Central Division of the Old Red Sandstone.*—The fossils consist of scales, most of which have a strong bony structure, and a tuberculated or ridged surface of enamel,—teeth of several kinds,—fragments of jaws with teeth or sockets,—vertebræ and other bones of fish,—and ichthyodorulites; almost the whole having been more or less injured previously to their being enveloped in the conglomerate. Besides scales of the *Holoptychus Nobilissimus*, many of the other fossils are identical with those obtained from Scat-craig, near Elgin. The scales of the *Holoptychus Nobilissimus* are well known to occur abundantly at Clashbinnie in Perthshire, near the northern shore of the estuary of the Tay, and in the Old Red Sandstones of Fifeshire; from which it may be inferred that those strata belong to the same epoch; but, as no good natural sections of these rocks, exhibiting the succession of the inferior beds, can be obtained, it is important that the identification should not depend on the remains of a single species, which is stated to occur also in the upper division of the system ('Silurian System,' pp. 137 and 601), and in strata directly below the coal in Fifeshire (Edin. Journ. of Natural and Geographical Science, No. 2; and Edin. New Phil. Journ. July 1833).

The drawings of the most remarkable fossils from the Findhorn, &c. will afford the means of a more extensive comparison, the results of which cannot be unimportant. I am already enabled, through the kindness of Mr. Noble, to identify portions of the beautiful ichthyodorulite (figs.* 1 and 2, drawing 33) found at Clashbinnie, with fragments from the Findhorn and from near Elgin†. The convex bony scale (fig. 4, drawing 20) also appears to be the internal surface of that figured by Dr. Fleming in the 'Edinburgh Journal of Natural and Geographical Science,' fig. 3, in which the engraver has failed to represent its arched pent-roof form seen in the specimen; and I observed an impression of the same kind in the quarry of Clashbinnie, which was unfortunately destroyed in attempting to remove it. Some additional observations on the figured specimens will be added in the form of an Appendix to this paper ‡.

On attentive examination of all the specimens from Burdiehouse to which I could find access in Edinburgh, and of the fine collection from the same place in the possession of Mr. Robertson, of Inverugie House, near Elgin, I failed to discover a single specimen that could be identified with any of the fossils of the central division of the Old

[* These drawings do not accompany the MS.—Edit.]

† It will be observed in this important specimen, that scales of the *Holoptychus Nobilissimus* are found along with the ichthyodorulite; but from this no conclusion can be drawn as to their having belonged to the same animal, these scales being so abundant in this quarry as to be mixed in every block.

[‡ This intended Appendix, relating to the palæontological evidences, was never prepared.—Edit.]

Red Sandstone. Jaws and teeth resembling those of the species of *Megalichthys* and *Holoptychus* of the Burdiehouse strata occur both at Elgin and on the Findhorn; but when it is considered that so many singular and unknown forms have been already obtained from these rocks, I do not think that I need conceal my impression, that, in the present state of the inquiry, great caution is requisite in referring to particular genera fragments which may belong to creatures having little analogy to any known forms.

In a new species and genus of ichthyodorulite (figs. 1, 2, and 3, drawing 30) belonging to the family of *Ostraciontes*, from Scat-craig*, M. Agassiz observed that the arrangement of the cells and fibres of which it is composed resembled that in the spines from the Ludlow rocks; and a small specimen from the Findhorn is very similar in form to one of those interesting fossils. Other specimens have a structure like that of some singular bones and epidermal coverings found in the mountain-limestone near Edinburgh, and presented to the Museum of the Royal Society of that city by Lord Greenock; and in a polished section of the remarkable ichthyolite from the Clackmannan coal-field, in Dr. Fleming's possession, I detected a bone, the structure and outline of which correspond exactly with one from the Findhorn (fig. 6, drawing 20). This similarity of structure is, however, consistent with the widest difference in the external form of the animals.

*Section through the Middle and Inferior Sandstones on the Burn of Lethen* (Section, Pl. XI. fig. 4), *showing the superposition of the Cornstone Series to the Fish-beds of Lethen.*

[This section is described from Dr. Malcolmson's MS., with some slight verbal differences, in Mr. Gordon's Memoir, pp. 33–36. In reference to the bituminized remains of fish, *op. cit.* p. 35, Dr. M. has added this note—"Many of the Orkney and Cromarty fish are converted into bitumen; and this seems most frequently the case when they occur along with plants. In a nodule in Mr. Miller's collection a cavity is filled with fluid bitumen." At the same page the following is a corrected paragraph—"A fact of much greater importance is that of their appearing to belong to the same plants recently discovered by Mr. Austen in the Old Red Sandstones of Devonshire, for an opportunity of examining the figures of which I am indebted to the kindness of Mr. Lonsdale." And the following note is added—"I have since found the same plants to occur abundantly in the Orkney Islands and in Caithness.—March 21, 1840."

The nodules mentioned, *op. cit.* p. 36, are also said by the author to "have a semicrystalline structure, radiated towards the surface; and the central parts occasionally approach in appearance to septaria. They burn into a tolerable lime. Their colour is pale-blue when first extracted, but they acquire a reddish tinge on exposure, and when rubbed or struck; and the animal matter of the fossils has often left deep-red stains, from its action on the iron of the stone. In minute stains of this kind in a nodule from Tynat, Mr. Gordon discovered some very small fish, probably the young of *Cheiracanthus*. Many of the scales and bones have the fine plum-blue colour of the Caithness fossils. One nodule sometimes contains more than a single specimen." Dr. Malcomson also observes—"It is not improbable that a fossil lately found at Duryden, in Fifeshire, and figured by Dr. Anderson, in his 'Account of the Geology of Fife,' as a beetle,

* This fossil is also found in the sandstones of the Findhorn. It has no central cavity.

may belong to the same tribe [*Pterichthys*: see Mr. Gordon's Memoir, p. 21], although the rocks in which they occur are supposed to belong to a different part of the system." And in a footnote he has added—"In specimens shown me by Dr. Anderson and Mr. Lyell, I observed that the external surface, instead of being marked with minute tubercles, is covered with a reticulation of ridges intercepting minute depressions." The concluding paragraph of the author's description of this Section is as follows:—]

We also found the plants at the termination of the ridge of red schistose sandstone, near the Hill of Rait, where some thin beds of limestone containing nodules, and layers of black elastic bituminous matter resembling fish-scales and impressions of plants, are associated with a coarse red sandstone conglomerate, and beds of schist with plants and nodules exactly resembling those of Lethen; and in the bed of a small stream which cuts deeper into the strata, a coarse-grained white sandstone is partially exposed. These beds appear to have suffered some disturbance; and during their deposition, denudation of the inferior strata has taken place, a thin band of clay containing nodules and *large angular fragments of the lower sandstone being covered by a solid mass of the same rock.*

*Fossils in the Valley of the Nairn.*

[To Mr. Gordon's account (*op. cit.* pp. 36–38) little can be added from the author's MS., besides the association of hæmatite with the barytes, except the following footnote:—"Since the memoir was written, scales and buckler-shaped bony plates have been found in the freestones extending along the shores of Nairnshire, from near Fort George to the quarry of King's Steps, east of Nairn. The most common of these specimens is the bony plate figured and described under the name of *Cephalaspis Gordonii* from the upper part of the central or cornstone division, at Boghole on the Burn of Lethen, near Brodie House. These scales were first noticed in an old wall by Dr. Gregor, of Nairn, and have since been found abundantly by Mr. A. Davidson and myself in all the quarries at the foot of the line of elevated shore east and west of that town. Although the country between the fossiliferous rocks of the vale of the Nairn and the seashore is obscured by drift, there can be little doubt (from the dip and direction of the strata, and the relative distances) that the Balfreish and Cantray beds dip under the sandstones west of Nairn, in the same manner as those of Clune pass under the cornstone series of the Findhorn. Some of the finest building-stones in the kingdom have been procured from the more siliceous of these beds."]

*Fish-beds of the Spey, and of Tynat and Buckie in Banffshire* (Pl. XI. fig. 6).—Returning to the eastern part of the district under description, it only remains to describe the rocks on the left bank of the Spey near Fochabers, and at Tynat and Buckie in the adjoining part of Banffshire, in which fossils of the same species as those from Caithness and Lethen have been found. These ichthyolites were discovered by Mr. Gordon and myself soon after I had found fossils on the Findhorn, and a multitude of details respecting them were collected with a view of determining their relations; but, as this has been since done more satisfactorily by means of the sections on the Burn of Lethen, it will not be necessary to occupy much time in their description.

High cliffs of the inferior great conglomerate are exposed along the south side of the Spey (Pl. XI. fig. 6) from near Fochabers as high as Orton, where it rests on the gneiss, which has been brecciated by the intrusion of quartz-rock. Opposite the termination of these cliffs, at Dipple on the other side of the river (fig. 6), beds of shale, alternating with thin bands of a red sandstone-conglomerate, are exposed in a low bank, at the foot of which the river probably once flowed, but which is now separated from it by some fields*. No rocks are seen on the same side of the river for a considerable distance above Dipple, the country being covered by a great accumulation of drift; but, previously to the excavation of the bed of the river, the great conglomerate must have extended to within a few hundred yards of the shales under which they appear to dip. The shale consists of a few thin strata of a soft unctuous argillaceous schist, containing a good deal of iron and very little lime; and it has proved injurious to the soil to which it was applied as a manure. A number of calcareous nodules are thinly scattered through it, which exhale a disagreeable smell, and are much withered from long exposure. From this cause, and the circumstances that seem to have attended the formation of the deposit, no well-preserved specimens have been obtained from this locality, with the exception of the singular arched bone and other parts of the *Coccosteus*, and various single scales of a radiated structure†. One of these specimens, belonging to Mr. Martin, has a zoned and radiated structure of great beauty, and so nearly resembles a unique specimen found by Mr. Noble at Clashbinnie, that I have had a drawing made of each (figs. 1, 2, and 3, drawing 3), this being the only instance in which these inferior beds have furnished any fossil similar to those of the upper series. These specimens should be carefully compared with each other, and with the scales of a species of *Holoptychus* from Burdiehouse, which has the same structure (fig. 2, drawing 23). It is proper, however, to state, that the middle layer of the scales of the *Diplopterus*, *Dipterus*, &c., presents the same radiated appearance, and in some individuals the rays are crossed by fine transverse bands, giving the scale, under the microscope, the appearance of a most beautiful and regular network. In some of the specimens the characters of the genus *Diplopterus* and of the *Osteolepis Uragus* are sufficiently evident.

A fine section of the superior beds is displayed on the bank of the river where it is crossed by the great North road (Upper beds, fig. 6), and has been several times described. On tracing the fish-beds

* This inference has been since confirmed by a detailed examination of the hill of Finlay Scat (1123 feet high by trigonometrical measurement), forming the south side of the vale of Rothes, and on the north part of which the conglomerate of Scat-craig near Elgin (so rich in the fossils of the middle division) rests. This hill is entirely formed of the great conglomerate which has been traced in various ravines to no great distance from Dipple, under the fish-beds of which it seems to pass.

† The curious bony ridge on the reverse of many of the scales at Dipple first assured us that the shales and nodules contained remains. It forms a useful practical means of distinguishing different specimens, and I have detected it in the ichthyolites of Orkney, Cromarty, Lethen, and Tynat. It belongs to the fish (figured in the drawings, plates 1 & 2) which has two opposite anal and dorsal fins, and a close-set row of fine equal comb-like teeth in both jaws.

down the stream towards the bridge, they are seen to be covered by several hundred feet of thin-bedded sandstones with pebbles and bands of red and grey micaceous shales, interstratified with harder beds of sandstone-conglomerate, in which a quarry is worked under a stratum nearly 30 feet thick of a very coarse conglomerate, containing large boulders of primary rocks and some angular fragments of sandstone. This passes gradually into a series of ferruginous and schistose sandstones and fine conglomerates, effervescing violently in acid and falling down into a red clay and grains of white quartz. The cement of the conglomerates is sometimes a nearly pure calc-spar. They resemble in lithological and agricultural characters the beds covering the ichthyolites of Lethen and Cromarty, but they are too deeply buried under drift to influence the fertility of the soil, except where applied as a manure. From the dip and direction of these strata, they were correctly inferred by Mr. Gordon to lie under the band of cornstone which extends from Elgin to the "Boar's Head" on the coast; but their true position with reference to the Scat-craig and Findhorn beds could not be ascertained previously to the discovery of the Lethen fossils, and of the extent to which denudation had taken place during the period of the deposit of the Old Red Sandstone.

*Sections through the Inferior Fish-beds at Tynat and Buckie in Banffshire* (Pl. XI. fig. 7).—Following the strike of the Dipple beds into Banffshire, we discovered at the Burn of Tynat, four miles E. of Fochabers, another series of beds containing ichthyolites (fig. 7). They consist of thin bands of shale, interstratified with red sandstones and conglomerates, which have been much disturbed, but dip to the north in the usual manner. The fossils generally occur in small, flat, compact nodules of the same outline as the fish; but fragments of the tuberculated bones have also been found in the finer conglomerates; and Mr. Martin discovered a very fine specimen of *Dipterus* in a red slaty sandstone (Tile-stone*), at *b* in the Section, Pl. XI. fig. 7. The total thickness of the strata between the upper and lower fish-beds does not exceed 50 feet. The arched bone of the *Coccosteus* (fig. 3, d. 4) was found in the lowest band of shale; and many finely-preserved specimens common to Lethen, Cromarty, &c., have been procured from the highest stratum, which is unfortunately very difficult to reach.

The inferior strata exposed in the bed of the stream higher up consist of a coarse conglomerate; and gneiss is seen a short way above. A little lower down, on the opposite side, the fish-beds have been brought, by a fault, into direct contact with a stratum of very coarse conglomerate, resembling that covering the Dipple and Gamrie beds, as represented in Pl. XI. fig. 8, the relations of which are obscured by a slip or fault that has brought down the superior red

* This name, applied by Mr. Murchison to the inferior division of the Old Red Sandstone of England, is very inapplicable to these rocks as they appear in Scotland; yet in this and other instances a certain degree of similarity of character can be traced.

sandstones so as to conceal part of the conglomerate. Immediately after, however, it appears in its proper position, undistinguishable in its characters from the great inferior conglomerate, wasting, like it, into round and pointed turrets, and having many of the largest boulders rent across. Above this stratum, which is about 30 feet thick, sandstone and coarse sandstone-conglomerates rapidly alternate, as on the Spey and at Gamrie; and from this to the sea a great thickness of friable red sandstones and fine conglomerates is exposed, identical with those at the Bridge of Fochabers, and in which no organic remains have yet been found. On the whole, there can be no doubt that the relations of these rocks are the same as of those at Lethen. [Pl. XI. fig. 9. represents the shale with nodules higher in the Burn, and red sandstones interstratified with the upper part of the great conglomerate.]

To the eastward the gneiss approaches the coast; and in the Burn of Golachy, friable sandstone, passing below into a compact limestone, containing angular fragments and pebbles of the neighbouring primary rocks, rests unconformably on the gneiss. The appearances at Buckie are more interesting. The Burn, descending from the contorted mica-slate of the hills near Letterfurie, passes through great beds of north-western drift, containing many angular fragments of the Morayshire sandstones and cornstones; and at the Mains of Buckie cuts through strata of gneiss, quartz-rock, and fine micaceous and chloritic schists, dipping to the south at a high angle. A little lower down, a thin vein resembling serpentine crosses the strata (of which it contains fragments) at right angles; and the stratified rocks are in several places much brecciated. On the sharp edges of the gneiss (Pl. XI. fig. 10), and *filling up the depressions between the projecting ledges*, a coarse hæmatite-red conglomerate rests, inclined to the north at a low angle; and the lower beds within high-water mark pass into a coarse limestone, which is occasionally worked. The conglomerate does not exceed 20 or 30 feet in thickness, and the only strata seen on it are a few patches of a red schistose sandstone, in which we found a distinct fragment of a tuberculated bone, apparently the same as those of Tynat, and some small scales. Beyond this the shore is occupied by quartz-rock, gneiss, &c., which are much brecciated and full of veins of calc-spar. These rocks exhibit the finest specimens of an elevated shore I have anywhere seen, and the fishing-villages are for the most part built on the raised beaches at the foot of their steep escarpments. The "Kings of Cullen" are great masses of hard red conglomerate, left in one of the bays of this ancient coast as memorials of the elevation of the land, by which they have been removed from the destructive influence of the waves. They contain no fossils.

*Conclusion.*—From the facts above detailed, we may conclude—

1st. That the primary stratified rocks of the southern shores of the Moray Frith were elevated at very considerable angles previously to the deposit of the Old Red Sandstone, and that the granite by which they are penetrated also belongs to a prior epoch. The elevation of the secondary strata to their present situation, the fracture of the boulders contained in the great conglomerate, and the faults and fissures in the sandstone, may have been caused by elevations in the line of the Grampians or of the great Caledonian Valley at an epoch, most probably, posterior to the deposit of the lower Purbeck beds, which, at Linksfield, have been bent and fractured by the elevation of the subjacent cornstone.

2nd. The great conglomerate and red sandstones, containing fish of the genera *Dipterus, Diplopterus, Cheirolepis, Cheiracanthus, Coccosteus*, &c., represent the Orkney, Caithness, and Gamrie rocks in Scotland, and the inferior division of the Old Red Sandstone of England.

3rd. On these are superimposed a series of marly conglomerates and sandstones (containing cornstones), which are characterized by a distinct and very characteristic series of fossils, and are equivalent to the central division of the Old Red system to the south of the Grampians, and in England.

4th, and lastly, the superior siliceous conglomerates and sandstones without fossils occur, but no indications of the coal-strata.

These conclusions are perfectly consistent with the appearances presented by the strata containing ichthyolites in other parts of the north of Scotland. The Rev. Mr. Clouston, of Shandwick, informs me that the succession of strata in Orkney* is as follows:—A coarse conglomerate, several hundred feet thick, rests on the primary rocks, and passes above into argillo-calcareous bituminous schists containing the fish; these schists, like the sandstones associated with them, dip from the primary rocks at an angle of 20°, and on these the soft red sandstones of Hoy are believed to rest. The whole of these strata are penetrated by greenstone-dykes.

At Cromarty, the great conglomerate dips under the sandstones (containing fish-scales) that rise to the hill called the North Sutor, but is hardly to be traced under the fish-beds of the South Sutor, the relations of which are otherwise nearly the same†. But, as I hope that the many interesting phenomena exhibited near Cromarty will be described in detail by Mr. Miller, I shall only state my conviction that the vertical position and altered appearance of the Old Red Sandstones on each side of this singular rock are not to be ascribed to the intrusion of the granite-veins, by which the gneiss, forming the summits and much of the sides of the Sutors, is penetrated, but to the eruption of a very siliceous trappean rock, posteriorly to the deposit of the lias, which has raised the gneiss into dome-shaped hills, and, near the remarkable rock called "M'Farquhar's Bed," has brecciated the sandstones, and altered the nearest strata that contain fish. The first observation that led to this opinion was made in 1837, at a place a little to the east of where the sandstones of the Bay of Cromarty wrap round the extremity of the hill. There,

[* See also Appendix.—Edit.]

† Geol. Trans. 2nd ser. vol. iii. p. 150.

a little promontory is formed by the gneiss rising on each side of a dyke of reddish-grey homogeneous trappean rock, approaching to hornstone, which is not acted on by acids, and fuses with great difficulty before the blowpipe. It appears to have flowed over the edges of the upraised gneiss, and the continuation of the dyke passes into the body of the hill. A small chasm is worn into the little cape at the line of junction of the upraised gneiss, *at the bottom of which and under the trap the usual granite-veins are seen in the gneiss.* I soon after examined the dykes in the lias, described by Mr. Miller some years before (in the 'Legends of Cromarty') as basalt, and since by Mr. H. E. Strickland as sandstone-grit; and notwithstanding the weight of authority in support of this latter opinion, and the fact that fragments of the smaller dykes effervesce in acids and crumble down into a siliceous sand, I am still of opinion, from the manner of their ramifications and the altered state of the limestones and shales through which they pass, that they form the upper part of dykes that penetrate the lias from the eruptive rock, forming the nucleus of the hill,—and whose existence not far beneath, Mr. Murchison long ago inferred from other appearances presented by these very remarkable hills. "If an adequate cause," he says, "be required to explain the great upheaving of the granite upon this coast, may we not seek for it in some deeply-seated volcanic agency, struggling (in vain) to expand its forces from beneath the vast mass of primary rocks, of which the mountains of the N.E. Highlands are composed?"*

It only remains to make one or two observations on the relations of the Gamrie Ichthyolites, the examination of which is rendered comparatively easy by Mr. Prestwich's very clear description of the district †. But the eye of an observer accustomed to contemplate the vast series of strata included in the Old Red Sandstone system at once perceives that there is no ground, in the general aspect of these rocks, to refer them to another formation; and I looked in vain for any instance of unconformity of the dip of the strata associated with the Ichthyolites to that of the inferior beds. Striking instances, indeed, occur of the strata on the opposite sides of the faults described by Mr. Prestwich having very different dips; but this does not imply unconformity of stratification, which was not to have been expected even if the Gamrie Ichthyolites had been part of the coal-measures. The Ichthyolites are associated with strata having a remarkable resemblance to those of Dipple, the coarse conglomerate above and the shales below (in which I found plants the same as those of Lethen) being almost identical in character; and I obtained from the thin-bedded red sandstone-conglomerate under this shale, fragments of tuberculated scales, such as occur in a *similar rock at Tynat*, and which can be referred to the singular fossils so abundant in Nairnshire. The series of sandstones, however, below the fossils attain a much greater thickness than in other places to the south of the Moray Frith, in which respect they resemble those of Cromarty.

* Geol. Trans. 2nd ser. vol. iii. p. 359. † *Ibid.* vol. v. p. 139.

It is necessary to add that I could detect no indications of the primary schistose rocks passing into the Old Red Sandstone, as mentioned by Mr. Prestwich (pp. 141 and 145); and that the micaceous schists at the village of Gamrie, coloured in his sections as the primary rocks, present an appearance not uncommon in various parts of the Old Red Sandstone, to which formation I have no doubt they belong. The gradual passage of the primary schistose rocks into Old Red Sandstone is so completely at variance with every observation I have had the opportunity of making in this part of Scotland, that I was glad to find the phenomena exhibited at the junction of these rocks near Troup Head, and in the neighbouring parts of Aberdeenshire, the same as I had been accustomed to witness, modified only by the occasional occurrence of grauwacke and trap-rocks*.

*Appendix.*

During October 1839, I visited the Orkney Islands, and have found Mr. Clouston's statement given above (p. 348) to be correct. The great conglomerate near Stromness rests on gneiss, which is traversed by veins of granite and of compact felspar, resembling those of Morayshire, and on a granite containing much red felspar. In the Island of Gremsey, between Pomona and Hoy, the granite appears to have been protruded in a solid form through the conglomerate, which contains beautiful crystals of quartz, galena, and heavy-spar. The bituminous flags with fish rest directly on the conglomerate. At Shandwick, in Pomona, I collected many specimens of the plants found at Lethen and Gamrie, which were associated with fish of the same species as at those places. The partings of these flags are sometimes coated with a pure bitumen entangled in calc-spar; and a mixture of galena and blende (as ascertained both by external characters and chemical examination) was

* Near the village of Aberdour, in Aberdeenshire, ten miles E. of Gamrie, the finer-grained red sandstones repose unconformably on the older rocks, without the intervention of the inferior conglomerates; and a little below the Manse, on the estate of Auchmedden, a fault occurs, which has brought shale-strata, containing nodules like those of Gamrie, into contact with the sandstones,—the strata on each side dipping at different angles, as represented in Pl. XI. fig. 11. In the few nodules which Mr. C. Smith and myself could procure, there were no fish; but I have no doubt that they would have been found had we had the means of digging. Between this and Troup Head the inferior sandstones and conglomerates are developed on the most magnificent scale, and form cliffs more than 600 feet in perpendicular height, against which the ocean constantly dashes; and it would rapidly waste them away, were they not protected by great masses of trap, and the hardness and position of some of the sandstone strata. Nowhere is more magnificent sea-scenery to be witnessed than along these stupendous cliffs, the careful examination of which would reward the geologist.

In October last, the Rev. Mr. Gordon, of Birnie, discovered, near Rhynie on the Bogie River, ten miles south of Huntly, in Aberdeenshire, in that great outlier of the Old Red Sandstone extending to Kildrumie Castle, and laid down in great detail in Dr. M'Culloch's map, thick beds of shale, with nodules similar to those of Lethen, &c., and containing remains of fish. This shale rests on a disintegrated yellowish sandstone, and is covered by a great thickness of yellow and red soft sandstones and conglomerates, like those of Cromarty and Tynat, on which thick beds of a hard pink sandstone rest.—Feb. 1, 1840.

found in the same situation. At several places near Stromness galena occurs in considerable quantity, associated with heavy-spar and stromnite, in what seems to be a line of fracture. At Scalpa Bay also, two miles south of Kirkwall, veins of quartz and heavy-spar occur along with iron- and copper-pyrites. Near Kirkwall I collected many specimens of a delicate bivalve shell, in general form like a *Cyclas*, but which does not possess characteristic generic marks. Along with these were some large scales of fishes, and at no great distance many fragments of the *Coccosteus*, some of them of very large size, and others which had belonged to very young animals. The above are the only shells yet found in the Old Red Sandstones of Scotland, and were pointed out to me by Mr. Robertson of Inverugie House, who collected them there some years before.

Near the Manse of Hoy, in the island of the same name, I found characteristic fish-scales and plants in the bituminous flags, not far from a vein of red hæmatite, formerly worked; and in the Dwarfie's Glen this black schist graduates into as oft red freestone, on which lofty cliffs of friable white sandstones, containing a few quartz-pebbles, rest. At the Kaim, on the N.W. shore of the island, this sandstone rests directly on the fish-beds; and at Bræburgh, an inaccessible ancient fortification, they form a perfectly vertical cliff, rising 900 feet from the ocean. From the very edge of this frightful precipice, I collected fine specimens of black oxide of manganese, which occurs in botryoidal veins, probably of contemporaneous formation with the sandstone. Dykes and great masses of amygdaloidal trap, abounding in nests of calc-spar, occur at the base of these cliffs, and near the Long Hope at the other end of the island.

On the opposite shore of the Pentland Frith, the same sandstones occur at Dunnet Head, resting on the bituminous flagstones of Caithness, which abound in remains of fish and plants identical with those of Lethen. At Huna and John o' Groat's House, I found fish-scales and plants in the red sandstones immediately above the bituminous flags near Duncansby Head, to the very summit of which the black shales with Ichthyolites have been elevated,—the yellowish sandstones being thrown off to either side of that magnificent headland. On the whole, a very careful examination of this coast left little reason to doubt that these headlands belong to the series of sandstones interposed between the lower fish-beds and those of the central or Cornstone division of the Old Red system*.

* In a new flagstone-quarry a little to the south of the celebrated ichthyolitic deposit of Banniskirk, I found plants identical with those of Lethen, Gamrie, &c. These plants are also found in abundance near Barrogill Castle and Castletown, associated with the usual genera of fish.

The following section on the south side of the North Sutor of Cromarty, for which I am indebted to my friend Mr. Miller, enables us to extend the same inference to Easter Ross.

| | |
|---|---|
| | Drift. |
| About 100 yards between the Fish-beds and the Drift. | Crimson and brick-red sandstones. |
| | Yellow sandstones. |
| | Limestone and clay. |
| | Yellow sandstones, in thick beds. |
| | Limestone and shale, resembling fish-beds. |
| | Yellow sandstones. |
| | Shales and a few nodules with fish and plants, of the same kind as at Cromarty, Lethen, &c. (Thin.) |
| | Reddish-yellow sandstone; 70 feet. |
| | Great Conglomerate; 100 feet. |
| | Gneiss, broken up: veins not seen at junction, but numerous at a little distance. |

Mr. Miller informs me that the same plants and fish-scales are found in various parts of the low cliffs of red and yellow sandstones, extending from the opposite side of the Sutor to Tarbet-ness *.

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## *On the* Succession *of the* Older Rocks *in the* Northernmost Counties *of* Scotland; *with some Observations on the* Orkney *and* Shetland Islands. Part I.

By Sir R. I. Murchison, G.C.St.S., F.R.S., V.P.G.S., &c.

[Read February 3rd, 1858 †.]

[This communication is incorporated with the next succeeding Memoir.]

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* See Sedgwick and Murchison in Geol. Trans. 2nd ser. vol. iii.
† See Quart. Journ. Geol. Soc. vol. xiv. p. 501.

THE

# QUARTERLY JOURNAL

OF

# THE GEOLOGICAL SOCIETY OF LONDON.

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## PROCEEDINGS

OF

## THE GEOLOGICAL SOCIETY.

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December 1, 1858.

The Rev. Dr. John Anderson, Newburgh, Fife, J. D. Smithe, Esq., Madhopoor, Punjâb, Samuel Laing, Esq., Hordle House, Lymington, Hants, James Clarke, Esq., Westcott, Dorking, Walter Baldock Durrant Mantell, Esq., New Zealand, George Dixon, Esq., C.E., Whitehaven, John Augustus Tulk, Esq., Whitehaven, Major-General Emmett, R.E., Henry T. Plews, Esq., Bedale, Yorkshire, The Right Hon. Lord Kinnaird, Rossie Priory, Scotland, and Grosvenor Square, London, and Capt. H. H. Godwin-Austen, H.M. 24th Regiment, were elected Fellows.

The following communication was read:—

### *On the* Succession *of the* Older Rocks *in the* Northernmost Counties *of* Scotland; *with some Observations on the* Orkney *and* Shetland Islands.

By Sir R. I. Murchison, G.C.St.S., F.R.S., V.P.G.S., &c.

(Plates XII. XIII.)

[Part II. of this memoir, read before the Geological Society on December 1st, 1858, and Part I., read February 3rd, 1858, have now, by permission of the Council, been united by the Author.]

Contents.

CONTENTS (*continued*).



INTRODUCTION.—In this memoir I propose to give a general sketch of the succession of the stratified rock-masses which occupy the northernmost counties of Scotland, or those of Sutherland, Caithness, and Ross, followed by brief notices on the Orkney and Shetland Isles, as determined by former and recent observations.

Having commenced to labour in this region in 1826, I then simply gave, as a first result, the account of the Oolitic coal-field of Brora, and of the Lias and Oolites of both the east and west coasts, including the Hebrides, with brief allusions to the bituminous schists of Caithness containing fossil fishes *. For, although I even then had traversed portions of the crystalline rocks, I considered all such masses as out of the sphere of my observation, presuming that their mineral and other characters had been adequately made known by Macculloch and others who were looked upon as authorities. In short, it was deemed a sufficient effort for a young geologist, as I then was, to point out the relative position of certain members of the Secondary series, to collect their organic remains, and to show the relations of such strata to their equivalents in England.

In the following year Professor Sedgwick and myself, devoting our efforts to the examination of the structure of the Northern Highlands, produced a memoir in which, after a brief allusion to the older and crystalline rocks, we gave the first account of the true order of the Old Red Sandstone and superposed masses, which we then showed to consist of three parts, viz. Lower Sandstone and Conglomerates, Central Caithness Flagstone, and overlying Red Sandstones of Dunnet Head and the Orkney Islands †. In that same summer we also traced the position of the so-called primary limestones of Assynt and Durness, and ascertained that these were intercalated in great bands of quartz-rocks and surmounted by chloritic, micaceous, and even gneissose strata. We further affirmed that those crystalline masses, together with the granite and other igneous rocks which traversed them, had afforded the materials out of which the conglomerates and sandstones at the base of the Old Red Sandstone of the East Coast were formed. Thus far our original views have proved to be true. Owing, however, to stormy and wet weather which we encountered on the west coast of Sutherland, and our limited time, we were precluded from observing the true relation of certain vast masses of red conglomerate, which, occupying lofty mountains, have recently been shown to underlie the quartzose and crystalline limestones just

* Trans. Geol. Soc. 2nd ser. vol. ii. p. 313.
† I had visited the Orkneys during the previous year.

spoken of. In spite of torrents of rain, we had, however, observed that some of the sandstones and coarse grits of the West Coast were associated with such crystalline rock; but, unable to follow up the observation, we laboured under the erroneous conviction, in common with all our contemporaries, that the great mountainous masses of red conglomerate and sandstone of the West Coast were simply detached portions of the Old Red Sandstone of the East Coast, as they had been represented to be by all preceding authors. Nor was this inference to be wondered at; for at that time both Prof. Sedgwick and myself were entirely unacquainted with the true succession of the Lower Palæozoic Rocks below the Old Red Sandstone. This opinion respecting the age of the conglomerates of the West Coast remained, indeed, so fixed in the minds of all succeeding geologists, including Hugh Miller, that even in my own work, 'Siluria,' published in 1854, these North-Western conglomerates and sandstones, which I had not then revisited, were considered to be of the same age as those of the true Old Red on the East Coast of Scotland. In fact, notwithstanding the very able researches of Cunningham, in addition to those of Macculloch and Hugh Miller, no one had obtained a correct notion of the general order of those older rocks of the N.W. Highlands.

Just at that period (1854), my friend Mr. Charles Peach, already distinguished by discovering those fossil remains in the hard quartz-rocks of the maritime headlands of Cornwall* which enabled me to assign them to the Lower Silurian age, being sent from his Custom-House station at Wick to visit a wrecked ship on the north coast of Sutherland, discovered certain organic remains in the limestone of Durness, which, though imperfect, were unquestionably shells.

Now, as I had previously expressed the opinion that large portions of the so-called primary or crystalline rocks of the Highlands of Scotland would prove to be equivalents of Lower Silurian deposits in the south of Scotland †, I naturally felt anxious to revisit the spot where the important discovery had been made. Having requested Professor Nicol to accompany me, the results, as related to my own views, were given at the Glasgow Meeting of the British Association in 1855. Having procured some additional fossils (one of them a chambered shell), I then still more held to the opinion, that the quartz-rocks and their subordinate limestones were of Lower Silurian age. I also seized that opportunity of maintaining the dignity of the Old Red Sandstone of the N.E. of Scotland as a great geological series, and asserted my opinion, that it is the true and full equivalent of the Devonian group of other countries.

Still two essential points remained to be distinctly cleared up. Professor Nicol and myself had noted the infraposition of a red conglomerate and sandstone to the quartz-rock and limestone; but, foiled by heavy rains and mist, we could not follow out the line of junction, and ascertain the persistence of such order in the adjacent

* Trans. R. Geol. Soc. Cornwall, 1849, p. 103; and Quart. Journ. Geol. Soc. vol. viii. pp. 5, 13.

† Quart. Journ. Geol. Soc. vol. vii. p. 169.

mountains. Aware that Col. James, R.E., was about to visit that region early in the summer of 1856, to select a site for the purpose of observations on the density of the earth, I requested him to trace that line of junction. This he did successfully as regarded the mountains of Suilven and Queenaig, and showed, in a letter to myself, that the red conglomerate and sandstone were *unconformably* overlapped by the quartzite series. Later in the same summer of 1856, Professor Nicol greatly extended our previous observations, and drew those clear sections which are published in the Journal of the Geological Society*, showing that the old gneiss and its superposed conglomerate, as seen along a very extensive region of the Western Coast, formed really the buttresses upon which all the crystalline quartz-rock and limestone of the western parts of Ross-shire and Sutherlandshire reposed.

It was thus that the very high antiquity of the red conglomerate and sandstone of the whole of the N.W. Coast was determined; for not only was it shown to underlie strata which, as I had suggested, would prove to be of Lower Silurian age, but the edges of such subjacent conglomerate and sandstone were seen to have been eroded before such Silurian deposits had been laid upon them.

Having agreed with me as to the facts respecting the ascending order of, 1st, an underlying or old gneiss; 2nd, great red conglomerate and sandstone; and, 3rd, the quartzites and limestone with overlying gneissose rocks,—Prof. Nicol, influenced by the mineral analogy of a fossiliferous limestone being intercalated in quartzites which he rightly considered to be merely altered sandstones, suggested, theoretically, that these quartzose and calcareous rocks might prove to be the equivalents of the Carboniferous series of the south of Scotland, in which limestones are also enveloped in sandstones. But my associates will recollect that my fellow-labourer (than whom no man is more impressed with the desire to ascertain the whole truth) simply put forth this hypothesis until all doubt should "be removed by the discovery of better-preserved characteristic fossils†."

In thus speculating, Prof. Nicol thought that the imperfect fossils on which I had reasoned were inadequate grounds for my hypothesis. He was also unconvinced of the accuracy of my inference, as based upon a datum which I held to have been fixed long before by Sedgwick and myself, and to which I still adhere, viz. that the above-mentioned crystalline rocks, in parts of which the fossils have recently been found, are the *inferior* members of the great undulating mass of gneissic and micaceous rocks, which, rolling over to the East Coast, there constitute the basis out of which the bottom strata of the deposit known as "the Old Red Sandstone" are chiefly formed. Though still sceptical on this latter point, and waiting for a more accurate survey of the country than has hitherto been made, Prof. Nicol bows now to the fresh evidences of organic remains, and considers, with myself, that the quartz-rocks and limestones of the west of Sutherland are of Lower Silurian age.

* Vol. xiii. p. 23.

† See Nicol, Quart. Journ. Geol. Soc. vol. xiii. p. 36.

Another theory, which had been previously propounded by the lamented Hugh Miller, was, that the quartz-rocks and marble limestone of Sutherland might be the metamorphosed representatives of the Old Red and Caithness series on the East*. Independently, however, of the organic remains, both these views seemed to me to be incompatible with the physical order of the masses. For, if Sedgwick and myself did not err in supposing that the true Old Red of the East Coast reposed upon and was made up of the materials of an upper portion of these quartzose and micaceous rocks, it was manifest that such original strata could not be the equivalent of *either* of the posterior formations!

Seeing that the question would be still more satisfactorily settled if better fossils than those which Mr. Salter and myself believed to be Lower Silurian were obtained, I induced my friend Mr. Peach to renew his search and devote more time to it; and the result was a second collection of such well-defined forms as dispelled all doubt, and enabled me unhesitatingly to say that the suggestion I offered at the Glasgow Meeting of 1855 is absolutely correct, and that the rocks in question are truly Lower Silurian. Under these circumstances, I offered a general sketch of what I considered to be the order and succession of the older rocks of my native country, the Northern Highlands†.

Feeling, however, that there still remained several points which required a stricter examination, I again visited the North of Scotland in the summer of 1858. On that occasion I induced Mr. C. Peach to be my companion in the counties of Sutherland and Caithness, as well as in the Orkney and Shetland Islands‡; and I have only to regret that official business deprived me of his valuable assistance when I examined the more southern counties of Ross, Inverness, Moray, Banff, &c.

One of my main objects was to ascertain whether the view taken by Professor Sedgwick and myself thirty-one years ago, respecting the age of the yellow sandstones of Elgin, Morayshire, which we had grouped with the Old Red Sandstone, was correct. It was, in short, of great importance to determine whether the air-breathing lizard (the *Telerpeton*) which had been found in these rocks was really of that remote age, or whether these light-coloured sandstones might not pertain to the Oolitic and Liassic series, masses of which occur

* This view was propounded before the Physical Society of Edinburgh and printed in the *Witness* newspaper. The author was so obliging as to furnish me with a printed copy of the memoir, from which I have extracted the admirable description of the sandstone and conglomerate mountains of the West Coast, given at page 363.

† Read before the Geological Society, February 3, 1858.

‡ The officers of the Commissioners of the Northern Lighthouses were so kind as to convey myself and companion from Scapa Bay near Kirkwall, in Pomona, through the other Orkney Islands which I had not visited, to the furthest point of the Shetland Islands, and finally to disembark my companion and self at Cape Wrath, where we recommenced our survey of the North-west of Scotland. I shall ever remember with delight the society of Mr. Alexander Cunningham, the Secretary, Mr. Thomas Stevenson, the masterly engineer of the Lighthouses, and of Mr. W. Swan, the Mathematician, and Mr. Grant, the Registrar.

on the opposite side of the Murray Firth. In consequence, I re-explored part of my native county of Ross, and, thence passing into Morayshire, there made researches in the endeavour to fix the age of the yellow sandstones containing lacertine remains, and in this I was zealously assisted by my friend the Rev. G. Gordon, of Birnie. I followed the Old Red deposits into Banffshire, and was satisfied that the fish-bearing beds of the Spey, Tynet-burn, and Gamrie, occupy, like the Caithness flags, a central position in the Old Red series, and do not constitute the lower division, as had been previously stated in all geological works.

Lastly, in examining the same series as exhibited on the S.E. of the Grampians, I was convinced that the grey flagstones of Arbroath and Dundee, and the flanks of the Sidlaw Hills, there form the base of the same natural group, and that the Red Sandstone of Perth graduates up into those yellow sandstones of Fife, which, being charged with certain fishes peculiar to the deposit, are distinct, on the one hand, from the central or Caithness beds of Old Red Sandstone, and from the lowest beds of the Carboniferous System of Scotland on the other. The following observations will not be given in the order of my tours, but by beginning with the oldest rocks and ascending to the youngest, as in preceding communications.

In offering this general view, I beg my associates to dwell chiefly on the facts adduced, and not to judge a memoir which relates particularly to the northernmost counties of Scotland, with a few allusions to the Orkney and Shetland Islands, by the incidental expression of my own speculative opinion respecting the more southern parts of the Highlands. Let me add, however, that even that addition has not been solely drawn from the few leading data to which allusion is here made, but is the result of several visits to different parts of the country. My companion in the year 1827, Professor Sedgwick, will recollect how, on the summit of Ben Wyvis, we then regarded its micaceous and gneissose flagstones with little other interest than as parts of those rocks out of whose debris the lower conglomerate of the Old Red Sandstone had been formed. Little did we then anticipate that in a few years we should both be actively engaged in the classification of various formations of much higher antiquity than the Old Red Sandstone, then regarded by us with such veneration, and which by their order and organic remains would enable geologists to decide upon the real age of the stratified crystalline rocks of the Highlands!

In concluding this introduction, which may at the same time be considered a *résumé* of the facts to be detailed in the memoirs which follow, a few words only need be said upon the great change which must now be made in all geological maps of the Highlands of Scotland. The gneissose and quartzose rocks, limestones, chloritic schists, micaceous schists, indeed, may remain as lithological subdivisions of groups; but the order of the *legend* attached to Macculloch's Geological Map of Scotland must be essentially changed, for Lower Silurian fossils are now known to occur in rocks near the bottom of the primary crystalline scale.

Not pretending to define the exact boundaries of the formations as now divided, I have still endeavoured to colour roughly a little geological map* of the Northern Counties and the Orkney Islands (Pl. XII.). In doing this, I have separated the old or fundamental gneiss from the younger quartzose and Lower Silurian series, with which Macculloch had merged it, by interpolating a great formation of Cambrian age, and have shown that the true Old Red Sandstone, overlying all those rocks, is marked by that triple division which so distinguishes it in Caithness and the Orkney Islands.

In treating of the Old Red Sandstone, I trust that the endeavour which I have made to demonstrate that the strata with *Cephalaspis Lyellii*, *Pterygotus Anglicus*, and *Parka decipiens*, which really lie at the base of all that series, are certainly of higher antiquity than the bituminous fossil-bearing schists of Caithness, will meet with the approbation of my associates.

The separation of the older and younger gneiss is, of course, easily effected in those tracts, where, as along a large portion of the North-west Coast, the great intervening conglomerate and sandstone of Cambrian age, as well as certain Lower Silurian rocks, occur; but there are doubtless more points than are known to me, in the interior or eastwards, where the old gneiss may be at once covered by younger rocks without the intervention of any such conglomerate or sandstone. In short, the general section (fig. 1) is to be considered as the diagrammatic sketch of my own views respecting the true order of succession, founded on data obtained by other inquirers as well as by myself.

The reader will well understand that some such view as is here presented is absolutely called for in order to clear up the scepticism which prevailed in the minds of the most eminent geologists respecting all the so-called Transition rocks before the new classification, as established upon superposition and organic remains, was propounded. So strongly was this felt, that in his last work, 'A System of Geology,' published in 1831, Macculloch thus writes:—"As the nature and boundaries of this class [the Transition rocks] have never yet been defined or proved, I have not given it a place in this work among the facts of geology. Yet if it really should be established by future and better observations, I shall owe the science an apology to which I cannot yet consider any geologist entitled†."

*Fundamental Gneiss.*—The most ancient stratified rock in Scotland, and, as far as I know, in the British Isles, is that gneiss which is exhibited in the north-western shores of Ross and Sutherland, where it forms the rugged basement of the whole stony superstructure, and has been well described by various authors, from Macculloch and Jameson to Cunningham. This rock is, even mineralogically, distinguishable from a younger metamorphic rock, which has also

* This map will be issued in a subsequent Number of the Journal, it being my intention to revisit the Highlands this summer, in order to satisfy myself still further on some doubtful points,—particularly in respect to the Reptiliferous sandstones of Moray.

† *Op. cit.* vol. i. p. 469.

Fig. 1.—*Diagrammatic Section, showing the General Succession, in ascending order, across the North Highlands from W. to E.* (Distance about 85 miles.)


*a*. Fundamental grey gneiss with red granite-veins. *b*. Chocolate- and red-coloured Cambrian conglomerate and sandstone. *c*. Lower Silurian rocks, consisting of—$c^1$, Quartz-rock with *Annelides*; $c^2$, Limestone with fossil shells; $c^3$, capping of quartz-rock. *d*. Crystalline schists and flagstones, occasionally chloritic and micaceous, often quartzose, and sometimes constituting flaglike gneiss, though in some spots they are little-altered flag-like sandstones. [* Igneous rocks, whether granite, syenite, porphyry, or greenstone, &c. These occur at various horizons, and are in some places interstratified and contemporaneous, and in others eruptive. Thus, large-grained porphyry occurs below *a* and *b*; greenstone and hypersthenic rock, with serpentine, are associated with *c*,—particularly $c^2$; syenitic and porphyritic rocks protrude between *c* and *d*; whilst these and true granites of several varieties, forming larger masses, burst through *d*, and are alone represented in this generalized section; the stratified rocks in contact (*d**) being highly altered and dislocated.] *e*. Lower conglomerate and sandstone of the Old Red Series, made out of all the above-mentioned rocks. *f*. Caithness ichthyolitic flagstones, or middle beds of the Old Red. *g*. Upper Old Red Sandstone of Caithness and the Orkney Islands, Tarbet-ness, &c.

been called gneiss, and has not as yet been distinguished from the older gneiss on any map, though the two are separated by vast formations of Cambrian and Lower Silurian age. (Compare this order with that of the maps of Macculloch and Cunningham †.)

It is, however, well exposed, as forming the low maritime headlands of Sutherland and Ross. This old gneiss is here and there traceable to Cape Wrath and the western side of Loch Eriboll. It is also represented in the woodcut, fig. 1, as lying beneath Cambrian red sandstone and conglomerate. The same order extends southwards along the west coast of Ross-shire ‡. The prevalent strike of this old gneiss is E.N.E.–W.S.W., the strata being variously inclined at high angles, and highly contorted. The body of the rock, being usually hornblendic, is also often penetrated by powerful granitic veins. This older and massive gneiss, usually of darker grey colours and of greater specific gravity than the younger rock hereafter to be described, is seen to subside to the east beneath the overlying formations, whether they consist of red conglomerate and sandstone, near the West Coast, or of quartz-rocks with limestone and mica-schists that appear at a short

† Transactions of the Highland Agricultural Society, vol. for 1839.

‡ See Nicol, Quart. Journ. Geol. Soc. vol. xiii. p. 19.

distance eastwards. It will be for future geologists to observe the extent to which this old rock may rise to the day in the central or eastern portions of the Northern Counties of Scotland. For, although I have been unable to detect its reappearance in Sutherland or Ross-shire to the east of the tracts extending from the west side of Loch Eriboll to Loch Assynt, it may well reappear in various parts of the wild and trackless interior which I have not explored. This old gneiss often occupies platforms of no great altitude, and for the most part constitutes those low, rounded, bare hills which resemble in outline the waves of a rolling sea. The spectator who, ascending to the summit of Ben Stack (one of the loftiest points reached by the old gneiss in Sutherland, and 2363 feet above the sea*), looks westward, observes, between him and the sea of Scourie Bay, a countless quantity of small lochs or tarns interspersed among the hollows of this brown-clad barren and rugged waste. On descending to examine the lower tract, he finds the surface frequently rounded off and polished like the "roches moutonnées" of the Alps; and, observing numerous striæ or scratches usually divergent from the central mountains, and following the lines occupied by the principal lakes or maritime fiords, he can have no doubt that, in the glacial period, the North-west of Scotland must have been very much in the present state of Greenland as described by Rink,—*i. e.* the central mountains occupied by snow and ice, from which vast glaciers are protruded to the lateral fiords or bays.

Whether it be examined at Cape Wrath on the shores of Loch Laxford, or in the bold cliffs near Scourie opposite the Island of Handa, in the Kyles of Strome or in the Bay of Loch Inver, the older gneiss has everywhere the same grey hornblendic basis, traversed by many veins of bright-pink granite. In ascending from the village of Loch Inver to Drum Swordalan, the geodes and veins of hornblende are indeed so rife as to constitute the chief masses of the rock.

This old gneiss chiefly occupies the cliffs along the western shore of the Kyle of Durness; and in a little burn adjacent to the Ferry House, the rock is charged with asbestos and actinolite.

*Cambrian Red Sandstone and Conglomerate of the West Coast.*—The ancient gneiss (*a*) of the general diagram (fig. 1) is seen in

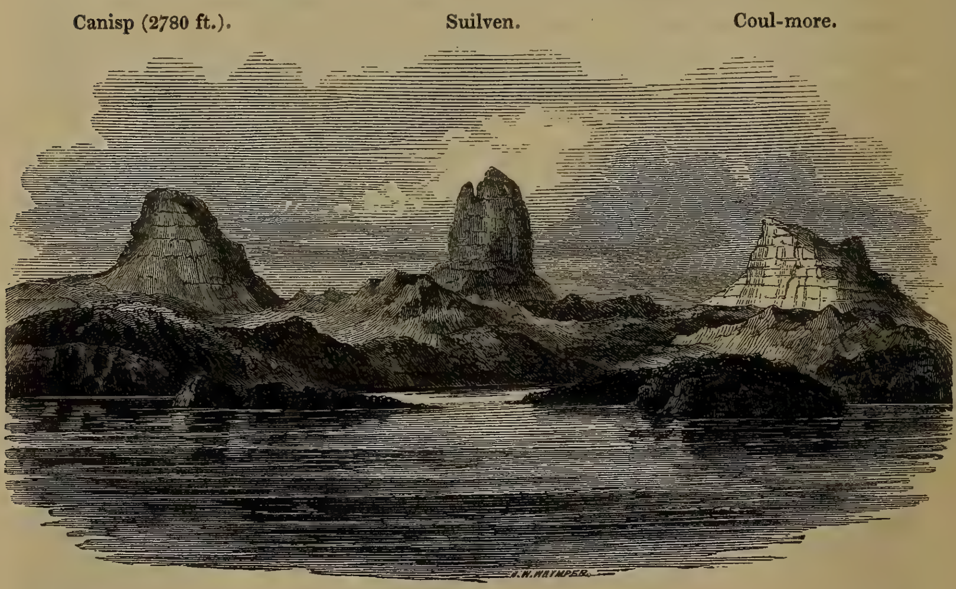
* By the kindness of Col. James, the Superintendent of the Ordnance Survey, I have been favoured with the following list of the heights of the principal mountains in Sutherland, which cannot but prove useful to the readers of this memoir, and those interested in the physical structure of the North-western Highlands:—

| | Feet. | | Feet. |
|---|---|---|---|
| Ben Clibrig | 3157·6 | Ben Horn | 1708·4 |
| Ben Hutig | 1340·0 | Ben Armin | 2332·3 |
| Fashven | 1495·7 | Ben Hie | 2862·3 |
| Cnoc Ghuibhais | 975·7 | Ben More in Assynt | 3235·5 |
| Suilven | 2396·1 | Canisp | 2780·2 |
| Ben Stack | 2363·8 | Ben Spionno | 2535·4 |
| Carnstackie | 2629·2 | Arkle | 2578·3 |
| Sarwhal More | 2548·9 | Ben Hope | 3040·7 |
| Foinaven | 2979·1 | Glashven | 2542·9 |
| Ben Laoghal | 2505·5 | Queenaig | 2673·0 |

many places along the north-western coast of Sutherland and Ross to be surmounted by great masses of dull-brown, red, and chocolate-coloured sandstone and conglomerate (*b*). This superposition is peculiarly well exhibited in the lofty and pyramidal mountains of Coulmore, Suilven, Coulbeg, Canisp, and Queenaig. When viewed from a boat at sea, these relations are precisely as Macculloch described them, and just as they are shown in fig. 1. But whilst their inferior relations were long ago well known, it has only been recently ascertained, as explained in the Introduction, that, as a whole, these north-western conglomerates and sandstones lie *unconformably* subjacent to the series of quartz-rocks with fossiliferous limestone ($c^1\ c^2\ c^3$) as well as to the micaceous, gneissose, and chloritic schists (*d*) which occupy so large a central portion of the Northern Highlands.

The conglomerate and sandstones of the North-west Coasts, which occupy this low position in the geological series, and which have on the whole a strike from N.N.E. to S.S.W., are, in truth, similar in lithological character to the purple and chocolate-coloured grits and pebble-beds of the Longmynd, which in the earlier days of our science were termed "Compound Sandstone" by Townson, and which were subsequently described at some length by myself, when I first showed that they formed the real base of all the Silurian series of Shropshire and the adjacent counties (see 'Silurian System,' p. 253, pls. 31, 32, and 'Siluria,' new edit. p. 23).

Fig. 2.—*Mountains of the West Coast of Sutherland and Ross.* (From 'Siluria,' new edit. p. 198.)




These rocks, as they appear on the coast of Sutherland, have been so truthfully and poetically described by Hugh Miller (though he then, like myself, thought they were Old Red Sandstone), that in reproducing this woodcut from 'Siluria' I willingly transcribe the words of that lamented author:—

"Rising over a basement of rugged gneiss hills that present the appearance of a dark tumbling sea [the dark lower rocks of the preceding sketch], we descry a line of stupendous pyramids from 2000 to 3000 feet in height, which, though several miles distant in the background, dwarf by their great size the nearer eminences into the mere protuberances of an uneven plain. Their mural character has the effect of adding to their apparent magnitude. Almost devoid of vegetation, we see them bared by the line of the nearly horizontal strata, as edifices of man's erection are bared by their courses of dressed stone; and, whilst some of their number, such as the peaked hill of Suilven, rise at an angle at least as steep and nearly as regular as that of an Egyptian pyramid, in height and bulk they many times surpass the highest Egyptian pyramid. Their colours, too, lend to the illusion. Of a deep red hue, which in the light of the setting sun brightens into a glowing purple, they contrast as strongly with the cold grey stone of the gneiss tract beneath, as a warm-coloured building contrasts with the earth-tinted street or roadway over which it rises *."

The occurrence of powerful red conglomerates on the south-western parts of the coast of Scotland, as shown by Mr. Carrick Moore and myself to be intercalated in the Lower Silurian rocks †, has indeed already prepared us for this identification of these still older Cambrian conglomerates as rising out to the north-west of the same country, where, resting upon the oldest known gneiss of the British Islands, their eroded surfaces are irregularly overlapped by quartz-rocks and limestones which are proved by their fossils to be of Lower Silurian age.

The local distribution of these Cambrian conglomerates and sandstones of the North-western Highlands, whose maximum thickness as exposed to day is not less than from 2000 to 2500 feet, is demonstrated by the fact, that, in proceeding a few miles only to the east, or into the interior, the fundamental gneiss is either laid bare or is seen to be at once covered by the powerful quartz-rock and limestone series, to the exclusion of those Cambrian rocks which range from various western headlands of Ross-shire to the bold promontory of Cape Wrath in Sutherland ‡.

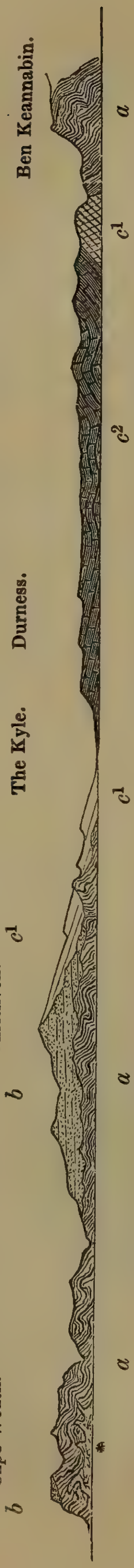
At Cape Wrath, which I had not visited since the year 1827 (when the lighthouse was building), I observed, on its western slope and summit, that the rocks of old gneiss were covered by beds of finely rounded pebbles, which disintegrate into very fine gravel. These beds of the Cambrian rock dip away very slightly (8°) to the W.N.W.,—all the pebbles in this conglomerate varying in size from one inch to $\frac{1}{4}$ of an inch, and being made up of fragments of the subjacent old gneiss. In following the coast-ridges to the east, or the Kyles of Durness, the lowest strata of the rock (*b*) are seen to graduate up into the usual red- and purple-coloured hard sandstones

* This description was read before the Physical Society of Edinburgh in 1854, in the memoir in which Hugh Miller propounded the theory respecting the quartz-rocks and limestones, to which allusion is afterwards made. The whole was printed in the 'Witness' newspaper, and transmitted by the author to myself with an explanatory letter.

† Quart. Journ. Geol. Soc. vol. vii. p. 149; and vol. xii. p. 359.

‡ See Trans. Geol. Soc. 2nd ser. vol. iii. p. 155.

Fig. 3.—*Transverse Section across the Durness Basin.* (Looking North. Distance about 14 miles.)




*a.* Fundamental gneiss, with granite-veins (*). *b.* Cambrian conglomerate and sandstone. $c^1$. Quartz-rock, with *Annelides*. $c^2$. Durness limestones, with Lower Silurian fossils. (N.B. Near to the right extremity of the Section igneous eruptive rocks penetrate $c^2$ on the sea-shore.)

which on the west rise from the cove of Clash-carnach to the summit of Skrishven (1213 feet above the sea), on the eastern flank of which they are unconformably overlapped by the lowest beds of the quartz-rock ($c^1$), which dip away to the E.S.E. and form the base of the Lower Silurian rocks of Durness, as shown in the Section, fig. 3.

In the interior of the tract called the "Parph," or the mountainous district lying between Durness on the N.E. and Loch Laxford on the S.W., these Old purple sandstones are largely developed, also capping the fundamental grey gneiss. They are indeed well exhibited near the summit-level of the high road to Scourie, or at the Gwalin Inn, whence they are seen to pass under the great quartzose Silurian series on the east. They extend, however, very little further to the east, since the gneiss rising in the western flanks of Foinaven and Ben Stack is at once covered by the lower quartz-rock. The Cambrian sandstone is again magnificently displayed in the western cliffs of the Island of Handa, where it constitutes cliffs upwards of 500 feet high, much frequented by sea-fowl, and where the strata, slightly deviating from horizontality, are also laid open by fine vertical fissures; the dip inclining, on the whole, a few degrees to the S.E. Again, in the promontory of Rhu Storr, or the Point of Assynt, and all along the shores of Lochs Inver and Enard, the fundamental gneiss is unconformably superposed at a little distance inland by masses of the Cambrian Red Sandstone, which, to the south of the Kyles of Strome, rise into the lofty peaks forming the chief beauty of the tract of Assynt and constituting from north to south the detached mountains of Queenaig, Suilven, and Canisp, each separated by lower tracts of fundamental gneiss, as in the preceding woodcut, fig. 2, and thence extending into similar ranges in Ross-shire. On this occasion I explored carefully (the weather favouring) the eastern flanks of Suilven, where the nearly horizontal strata of that noble mountain are seen in their greatest extent to repose upon the fundamental gneiss. It is about halfway along the side of the mountain that the whole mass has been affected by a great E. and W. fault, to which my attention was first called by Colonel James.

The upland longitudinal depression separating Suilven from Canisp is in its lowest part occupied by Loch Ganiveh, the old gneiss hills on the sides of which offer many fine examples of the polishing, scratching, and rounding action of a glacier which must have passed along the gorge. In proof that the movement was towards the sea, we found at Loch Inver many blocks of that large crystallized felspathic porphyry which my active and zealous companion, Mr. Peach, had in the previous year traced around the flank of Canisp. As seen from the shepherd's hut called Clacharie, the chocolate-coloured bands of the lofty Suilven are partially fretted by pendent stalactites like icicles, whilst a few green grassy slopes occur at intervals, to give greater effect to the marked horizontality of the whole, which is strikingly contrasted with the highly inclined gneiss on which it rests. Here the base of the sandstone is a coarse brecciated conglomerate. The fault traversing this mountain, and which at a rough estimate seemed to me to be an upcast to the south of from 800 to 1000 feet, is, as far as I could judge, parallel to a great fault in the adjacent mountain of Canisp, observed by Mr. Peach.

Whilst the unconformability of the Old Gneiss to the Cambrian Sandstone is everywhere manifest, an equally clear discordance is exhibited between the latter and the overlying quartz-rocks; and of this feature many examples will be presently given.

In the depression between Canisp and Suilven, Mr. Peach detected the existence of the strong band of red porphyry, with large crystals of felspar, which is interposed between the gneiss and the great conglomerate*. Thus, one of the earliest coarse sedimentary accumulations in the crust of the globe seems to have been ushered in by the eruption and spreading out of porphyry associated with red conglomerate,—a phenomenon which has been repeated at intervals through the Silurian and Devonian periods to the conclusion of the great Palæozoic era, and strikingly during the accumulation of the Permian deposits. The pebble-beds of the North-western Highlands, though traceable for a considerable distance along a given north and south zone (evidently an ancient line of shore), diminish rapidly if followed on their dip, and are thus seen to be accumulations, which, though of great thickness in some spots, thin out and disappear in the course of a few miles. In no country is this feature better seen than in following these Cambrian conglomerates of the N.W. Highlands to the E.S.E., when we distinctly see, as has just been said, the fundamental or old gneiss at once covered by the quartz-rock series, to the entire exclusion of any remnant of the old shore pebbles with their coarse grits and sands, which, at a few miles only to the west, clearly underlie all the quartz-rock series. The range of these conglomerates southwards along the western shores of Ross-shire has already been well detailed by Prof. Nicol; and his sections are so clear that I have simply to refer the reader to them†.

* Prof. Nicol has also noticed the presence of porphyry associated with the same rocks in Loch Broom. See Quart. Journ. Geol. Soc. vol. xiii. pp. 20, 21, 35.
† See Quart. Journ. Geol. Soc. vol. xiii. p. 23.

*Lower Silurian Rocks* ($c^1$, $c^2$, $c^3$), *in the form of Quartz-Rocks with intercalated Crystalline Limestone, followed by Chloritic and Micaceous Schists, and Younger Gneiss.*—These consist (in ascending order, as exhibited in the general section at p. 360) of—1. quartz-rock ($c^1$); 2. limestone ($c^2$); 3. quartz-rock ($c^3$); (*d*) micaceous and chloritic schists passing into a sort of gneiss, with repetitions of quartzose and micaceous flaggy rocks, &c.

Such is the succession observed in proceeding from the districts of Ullapool, Assynt, and Durness on the west, to the south-eastern border of Sutherland, where that county is bounded by Ross. With some local deviations and rolls which reverse the inclination, the prevailing dip of all these regularly stratified masses is eastwards, and for the most part to the E.S.E. or S.E. Let us first consider the inferior members of this group, as exhibited on the shores of Loch Broom and at Ullapool in the north-western extremity of Ross-shire, and as ranging thence to the N.N.E. through the wide parochial tracts of Assynt and Edderachillis, into Durness, throughout which they can be more or less continuously followed for a distance of not less than fifty miles, and always exhibiting the same order of a central mass of limestone with underlying and overlying quartz-rock strata, succeeded upwards by mica-schists and a younger gneiss.

*Lower Quartz-rock.*—The lowest beds, as seen in the west of Sutherland, rest, as before said, on the Cambrian conglomerate and sandstone (*b*), or, if that formation be absent, on the old gneiss (*a*). Their lithological characters have recently been so well described by Nicol under the name of *quartzite**, that I have little to add. Fine-grained, void of mica, and usually of a light-buff or greyish colour, but often weathering to a pure white, this siliceous band much resembles the Stiper Stones of Shropshire, and gives the clearest evidence that it is simply an altered sandstone, being not only regularly bedded and jointed, but also exhibiting here and there argillaceous way-boards, which have usually passed into schists. This band further resembles the Stiper Stones or the typical base of the Silurian rocks of Shropshire in containing Annelides (Pl. XIII. figs. 28–31) and Fucoids, which last also occur in the uppermost layers of the lower band and immediately beneath the limestone.

The minute cylindrical bodies which Macculloch supposed to be Orthoceratites have completely satisfied Mr. Salter that they belong to the class of sea-worms. I have therefore named them, in the new edition of 'Siluria' (1859, p. 222), *Serpulites Maccullochii*, in honour of the first discoverer of the oldest perceptible organic remains of the Highland rocks. (See Pl. XIII. fig. 31.) At the Bridge of Skiag, near Loch Assynt, an argillaceous course occurs upon the lower quartz-rock, containing casts of tortuous cylindrical bodies which are evi-

* I prefer adhering to the old name of Quartz-rock, by which these rocks have been known from the early days of Scottish geology, and which I long ago applied to the Lower Silurian Stiper Stones, showing that they were altered sandstones (Sil. Syst. p. 268 *et seq.*). The term "quartzite" has been adopted from the French.

Fig. 4.—*Transverse Section across the Assynt Country.* (Looking South. Distance about 6 miles.)


*a.* Fundamental gneiss, with granite-veins. *b.* Chocolate-coloured sandstone and conglomerate (Cambrian). $c^1$. Whitish quartz-rock (Lower Silurian), with *Annelides.* * Position of the large Annelide-tubes. $c^2$. Dark-coloured limestone, containing chambered shells (Lower Silurian). $c^3$. Quartz-rock, capping the limestone.

dently referable to marine plants or fucoids * ; but nowhere has anyone—not even the keen-eyed Peach—collected a form which can be referred to terrestrial vegetation. The exact position of the *Serpulites Maccullochii* and the Fucoids, as thus given, is to be traced over a considerable area, both in the environs of Assynt and in those of Loch Eribol.

It is to be observed that the siliceous courses in which annelides occur, are not to be considered a porous granular quartz, as stated by Macculloch, but as a hard compact rock which simply becomes porous upon weathering, when the fossils are best exposed.

Instructive sections in ascending order may be made, either from the Kyles of Strome or from Loch Inver, in Sutherland. The former, however, is by far the most satisfactory, because, by slight deviations only from the road, the passing traveller may satisfy himself of the truth of all the data of superposition. Quitting the rugged bosses of gneiss at the Ferry, and ascending to the summit-level of the road, he soon meets with layers of the chocolate-coloured Cambrian sandstone, which, sweeping down to the road from the lofty precipices of Queenaig, dip to the W.N.W. at the slight angle of 5° or 6°; so nearly do the beds of that very ancient rock approach to horizontality.

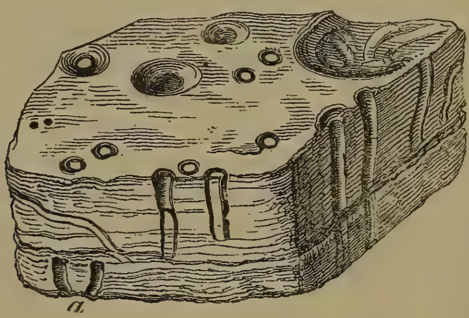
Here there is no ambiguity; for the chocolate-coloured Cambrian rock is clearly superposed by sheets of the compact quartz-rock, which dip from 20° to 25° to the S.E. In short, no unconformity can be more striking; and the quartz-rock, at the summit-level of the road, rests on the shoulders

* The fucoid-bed and its associates were traced by Mr. Peach from Ledbeg near Loch Awe, by Stronchrubie, Inchnadampf, Assynt, Bridge of Skiag, and thence towards Kyle Scow, and at two of these places Prof. Nicol and myself had previously detected it. Mr. Peach observed them in precisely the same position on the eastern shores of Loch Eribol.

of the hill, then rises high upon the truncated edges of the Cambrian rock, and even caps one of the summits of the noble Queenaig. The lower beds of the quartz-rock, which rest upon the Cambrian sandstone, are here very striking, from exhibiting on their surface large round knobs on the tops of cylindrical bodies which pass through several layers and are unquestionably the infillings of excavations made by *Annelides*. (See Pl. XIII. figs. 29, 30.) The quantities of these pipe-shaped bodies are astonishing; and as they also occur in the same stratum (*i. e.* near the base of the lower quartz-rock) and on the west shore of the Kyle of Durness, we may infer that they are the oldest vestiges of life which can be detected in the Lower Silurian rocks of the North Highlands.

In illustration of the manner in which these tubular bodies traverse the layers of quartz-rock or crystallized sandstone on the north-eastern flank of Queenaig, I may here repeat a woodcut from p. 41 of 'Siluria' (new edit.), representing Annelide-burrows in the quartz-rock of the Stiper Stones, a well-known Lower Silurian rock of Shropshire. The trumpet-shaped openings, sometimes 2 or 3 inches in diameter, the tubular cavities, and the cylindrical casts (identical with forms found thirty years ago on the west shore of the Kyle of Durness by Sedgwick and myself), leave no room for doubt that they also represent the *Annelides* of the English Stiper Stones and of the Potsdam Sandstone or Lowest Silurian rock of North America (*Scolithus linearis* of Hall).

Fig. 5.—*Fossil Annelide-tubes* (Scolithus linearis) *from the Stiper Stones, resembling those from Assynt.* (From 'Siluria,' new edit. p. 41.)




Descending into the Vale and Loch of Assynt, upon the surface of the lower quartz-rock, its upper layers are clearly seen to become more schistose and shaly, and also to exhibit fucoidal and other impressions. Then the succeeding limestone expands in terrace over terrace, and is best exposed in mounting from the edge of the loch, or from the west by north, to the hill called Cnoc-an-drein, on the east by south. In this walk you pass over a succession of parallel ridges for the space of about three-quarters of a mile, each calcareous band dipping easterly at about 25°. Some of the limestone is of deep-grey or dull-blue colour; other parts are light-grey, whitish, and mottled: portions of it have been formerly opened out for marble-quarries. As Mr. Peach detected an Orthoceratite, there is little doubt that future researches in this rock will bring other fossils to light. In approaching its summit, the limestone becomes more impure, its uppermost band bearing a peculiar aspect, and intermingled with schist and shale,—some courses resembling volcanic ash or grit.

These beds are at once, as at Eribol, overlaid by beds of whitish and pinkish fine-grained quartz-rock; and thus in one and the same escarpment, and only a mile from the Inn of Inchnadampff, the limestone is seen to be fairly intercalated in the quartzose series; the last mounts up by Brebeg into the lofty mountains of Coniveall, which passing to the S.S.W. constitute a range of mountains that extends into Ross-shire.

On this last occasion we did not follow the Lower Silurian limestone further to the S.S.W. than Elphin, where, although it is partially changed into a white, hard, compact marble in the vicinity of certain eruptive rocks (syenite, porphyry, &c.), it still occupies precisely the same place in the series,—the lower quartz-rock being seen to sweep down in broad sheets from the Cambrian sandstone mountains of Suilven, Coulmore, and Coul Beg, and to be surmounted, at the base of the limestone hill of Knockin, by the mottled fucoidal shale-bands.

*Durness and Assynt Limestone.*—The lower quartz-rock, with its cap of fucoid- and serpulite-beds, is everywhere surmounted, in Durness as in Assynt, by a strong band of limestone, which, under the scrutiny of Mr. Peach, has afforded those organic remains which have enabled us to pronounce unhesitatingly that these rocks are of Lower Silurian age. Hard, marbled, veined, and occasionally divided by joints, this grey limestone is often highly siliceous. Not only does it assume in parts a cherty character, but in Durness it is filled with a profusion of geodes of chert or quartz, which assume fantastic shapes, and weather to a darker exterior than the body of the rock.

There, in a less well-preserved condition, some of the fossils, which were at first found at one or two spots only, have recently been detected by Mr. Peach in other localities of that extensive parish. The manner in which many of the fossils have been filled with siliceous matter and the manner in which the organic remains weather under such conditions, offer a striking analogy to the aspect presented by North American specimens derived from strata of the same age in Canada, and transmitted by Sir W. Logan.

In the environs of Inchnadampf, and particularly to the east of that place, the limestone forms noble terraces resting upon the lower quartz-rock, and is clearly overlaid by other quartz-rocks, which rise into Ben More of Assynt and other lofty mountains. The same order is seen at the Bridge of Skiag and other places, the fucoidal and shale beds always occurring in the upper portion of the lower quartz-rock; whilst on the road to Durness the whole ascending order is exposed, from the old gneiss upwards, when the spectator looks to the E.S.E. from the marine bay called the Kyles of Strome, over the mountains ranging into the interior*.

In Durness, beds of pure and very impure, highly cherty, and cavernous limestone alternate with altered schists and finely granulated and laminated hard siliceous sandstone of divers colours, both red and grey, as exposed in ledges upon the shore near Balnakiel. These hard and tough rocks are interlaced with geodes marking the lines of stratification, as well as by thin courses of flinty chert. The concretionary structure is well exhibited at Craig Sarsgrun, about three miles south of the Durin Inn†, where the concretions vary in size from an inch to several feet in length. The concretions are often white, sometimes pink, and therefore present a striking contrast to the dark-grey escarpment. Many of these beds are almost quartz-rock; but as they contain some calcareous matter, the natives usually call them all "limestones."

The geologist can easily detect the calcareous portions by the weathering of the escarpment, which presents partially eroded lines along the course of the small concretions. These rocks are all more or less affected by a slaty cleavage, which, being highly inclined, disposes the rock to jut out in sharp protruding bosses through the green sward by which the calcareous band is characterized.

Although the ascending order of the quartz-rocks and limestones is everywhere the same as in Assynt, *i.e.* a strong band of limestone interposed between masses of regularly stratified quartz-rock, the subjacent Cambrian conglomerate disappears in Durness, and the lower quartz-rock rests at once upon the old and fundamental gneiss. This is seen on the west shore of the Kyle of Durness, and also near Rispond upon the coast, in the escarpments of Ben Spionno in Durness, and at other places in the interior to the S.S.W., *i. e.* Ben Stack, &c. The western face of Ben Spionno is indeed entirely composed of the lower quartz, which, sloping down to the east by south to Loch Eribol, is there seen to dip under the limestone of the Chorrie Island and to form fine calcareous terraces along the eastern side of the loch. These limestone-bands are in their turn overlaid by other quartz-rocks. (See fig. 3, p. 364.)

During my last visit to the North-west in company with Mr. Peach, I confirmed what is stated in the previous sentences. Thus, proceeding from the district of the Parph, or from Cape Wrath on the W.N.W. to Durness on the E.S.E., the succession exposed in the accompanying section is admirably seen. The older gneiss and Cambrian sandstone (*a* and *b*) have been already spoken of; and on the

* Previous to my last visit, Colonel James had re-assured me that the limestone extending from Assynt to the N.N.W., by Glendhu, Mealhorn, Loch Dionart, and Camvel, to the eastern shore of Loch Eribol, occupies everywhere the same position I had assigned to it as subordinate to the white quartzose beds. The best section which he examined, in reference to this part of the succession, was along the course of the Lone River, which falls into Loch Stack; and there an overlying as well as an underlying quartz-rock is clearly exposed.

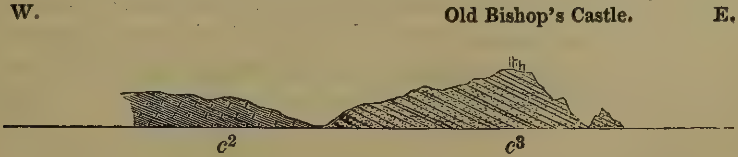
† The Inn of Durin, kept by Mrs. Ross, is strongly recommended to explorers, as also the Inns at Loch Inver, Inchnadampf, and Scourie.

eroded edges of the latter is seen to repose the lower quartz-rock ($c^1$) in thin flat-bedded strata usually weathering white, but here and there of a pinkish colour. It was in the higher part of this band that Professor Sedgwick and myself (1827), and Macculloch before us, observed certain cylindrical bodies, now known (as before observed) to be due to *Annelides*. Dipping to the E.S.E., these rocks are carried under the great mass of the limestone of Durness ($c^2$), which occupies several ridges over a maximum width of about three miles.

Examining its ridges both longitudinally and transversely, Mr. Peach pointed out to me, and particularly in the hard, cherty, and cavernous portions of the rock, many *Maclureæ* and a great abundance of *Murchisoniæ*, with some *Orthoceratа*. These fossils invariably occur in dark-coloured cherty and very fetid limestone, which occasionally presents a rugged outline as it peers through the rich grass of this sheep-feeding-ground. Some of the exposed points or knobs, which weather black, are surrounded or partially wrapped over by a tufa-like siliceous sinter, sometimes resembling a breccia, which conveys the idea of a boiling over of such matters when the rock underwent the metamorphism to which it has evidently been subjected. Even in this peculiarly hard matrix, my companion detected traces of fossils. The most marked of the external characters of the limestone is its coarse rugosity—the result probably of weathering upon its peculiar composition, and which gives the scarps of the rock the appearance of an elaborately wrought rustic basement of a Florentine palace. The best limestone is in the state of a cream-coloured compact marble; but no fossils have been discovered in that variety of the rock. Even in its siliceous condition, the limestone occasionally retains an oolitic structure.

Owing to breaks, undulations, and twists, it is difficult to form even a tolerably accurate estimate of the united thickness of all these beds of limestone; but in Durness, where they occupy successive terraces with little intervening grassy valleys, they cannot well be less than 500 or 600 feet thick. If the section be extended to the Old Bishop's Castle on the east (fig. 6), the observer finds that, after passing over

Fig. 6.—*Section of the Upper Quartz-rock to the east of Durness.*




$c^2$. Durness fossiliferous limestone.
$c^3$. Quartzose and micaceous flagstones.

a low ground covered by blown sand (the usual position of the upper quartz-rock in other places), he reaches a headland composed of overlying thin-bedded grey micaceous flagstone ($c^3$), which occasionally weathers white, like the promontory of the Whiten Head on the opposite side of the bay.

No one who has advanced from the west to the east, and left behind him the old gneiss, can for a moment fail in recognizing the distinction between this overlying crystalline flagstone and the old gneiss, though it also contains felspar as well as quartz and mica: it is not hornblendic and massive, and is void of granitic veins. In other localities, to be considered presently, it will be seen how the limestone is directly superposed by a band of pure white quartz-rock. One of the best detailed sections, showing the succession of the limestone, is seen to the north of the House of Balnakeil, and in some of the northernmost headlands, places in which Mr. Peach collected many of his fossils. Previous to my last visit, I had supposed (and Professor Nicol had published a section to show it*) that the Durness limestone was abruptly cut off by the old gneiss upon the east, between Durness and Loch Eribol. But such is not the case; for Mr. Peach had observed, and I confirmed his observation, that between the interior ridge of old gneiss which extends from the western foot of Ben Keannabin and the limestone of Durness, the dip is reversed, and the underlying quartz-rock is again brought up, lying between the gneiss and the limestone, as represented in the section, fig. 3, p. 364.

The reversal by which the Durness limestone is thus placed in a trough of quartz-rock and overlying limestone has been manifestly occasioned by a great upheaval of the old gneiss when acted upon by eruptive forces, of which clear signs are manifested in the adjacent Bay of Sangoe. There huge bosses of black hornblendic and hypersthenic rock stand out with serpentinous coatings,—the courses of the limestone in their vicinity being singularly altered, mottled and dolomitic.

Again, as we ascertained that Farred or Far-out Head consisted of the old gneiss, there is now no doubt that the limestone and underlying quartz-rock of Durness occupy a trough. The clearest proof of the trough-shaped arrangement of the strata is a little to the west, or inland, from the well-known limestone promontory in which the large caves of Smo occur. This limestone, which dips very slightly seawards or N.N.E., is highly altered, siliceous, and prismatized by a number of vertical lines of rude cleavage, which cause the rock to split into innumerable brittle fragments. On leaving the headland, and on mounting to the low-peaked hill of the quartz-rock called Sangoe Beg, certain white cherty and siliceous beds are remarkable as graduating into the lower quartz-rock, which is seen to rise gradually from under the limestone until the beds attain the high angle of 65°, the dip to the N.N.E. being traversed by the same rude vertical cleavage. A deep gully here alone separates the quartz-rock from the older gneiss.

Quitting the basin of Durness, including the large limestone island of Hoan, and passing across the noble longitudinal marine loch of Eribol, the geologist who proceeds to the E.S.E., or towards Ben Hope or Loch Tongue, has thenceforward a clear and unmistake-

* Quart. Journ. Geol. Soc. vol. xiii. p. 23. fig. 4.

able ascending section from the fundamental gneiss, which ranges from Ben Spionnach to Loch Soan on the west side of Loch Eribol. For he there sees the lower quartz-rock dipping to the E.S.E. from off the shoulders of the older gneiss hills, and even from the summit of Ben Spionnach, 2204 feet above the sea, and then plunging under the limestones of Island Chorrie and Eribol, as described on a former occasion.

As it had been doubted by Professor Nicol whether the quartz-rock which I had described as regularly overlying in some places the limestone of Durness, Eribol, and Assynt was not cut off from the latter by dislocations, I especially explored, in my last visit, the coast-ridge on the west side of Loch Eribol from the Ferry to the north. In that direction, or in the northerly strike of the beds, the limestone, which at first occupies several low hills resting upon the lower quartz which flanks the sea, thins out gradually to a very small band which under Cnoc Craggin and to the north of Heilam is seen to be fairly interpolated between the lower and a band of upper quartz-rock,—the latter being pure white, and all the strata dipping to the E.S.E. at about 18°.

In the hills extending towards the Whiten Head, where all the strata are exposed on the sea-cliffs, we pass over, in ascending, first the upper beds of the lower quartz-rock, charged with the Annelide-tubes and the *Serpulites Maccullochii*, and graduating up into the limestone by impure calcareous strata, and then the limestone itself with Fucoid-shale. Now all these beds of quartz-rock and included limestone are, I maintain, covered, as a whole, by the micaceous flagstones, schists, and younger gneiss of the higher hills, and these clearly extend to the Kyle of Tongue and the flanks of Ben Hope. The last-mentioned lofty mountain is indeed almost entirely composed of such micaceous flagstones (*d* of the sections), all of which have hitherto been mapped under the name of gneiss. The strata on the west shore of the Kyle of Tongue are literally almost sandstones.

In this way I not only satisfied myself that the section of 1827, showing a younger micaceous and gneissose flagstone series over the limestone of Durness and Eribol, was correct, but also that the latter, like many other Silurian limestones, was an accidental deposit, subordinate to a great siliceous or quartzose series. In fact, the limestone, so expanded at Durness as to occupy a wide basin, as well as on the large island of Hoan, thins out and disappears in a quartzose series as we proceed from Eribol towards the Whiten Head or the N.N.E.

In its longitudinal range from Loch Eribol to the South of Assynt, or for a distance of about forty miles from N.N.E. to S.S.W., the limestone performs precisely the same part, showing itself occasionally in thin courses only, either pinched out or scarcely traceable, but always fairly intercalated in the quartzose and crystalline rocks.

Thus, when not covered by moss and heather, the limestone crops out at several spots to the S.S.W., as at the head of Loch Eribol and in the Bealloch or depression between the grand mountains of Fionavin and Meal Horn,—the former composed of the lower quartz resting on old gneiss, the latter of the overlying flaggy and micaceous series. The limestone occupies a similar geological position to the east of Arkle and Ben Stack. There, though only visible at intervals through the thick covering of peat and heather of a deer-forest, the beds of limestone are to be observed dipping steadily to E.S.E. and quite conformably to the underlying quartz-rock, which slopes down in brown masses from the shoulders of Arkle and Ben Stack; the former exhibiting noble white precipitous faces on the S.S.W. The banks of Loch Stack and Loch More, extending from N.W. to S.E., naturally expose transverse sections of this regular succession from the fundamental gneiss through this overlying Lower Silurian series, —the Cambrian rocks having again thinned out and disappeared, as in Durness.

Ascending the mountain of Ben Stack, 2363 feet high, we found that the old gneiss, of which the mass is composed, was covered by a pebbly band, which formed the base of the quartz-rock, and passed eastwards into overlying sheets of the same; and these, on both the north and south shores of Loch More, are covered by thin bands of limestone, which in their turn, and particularly on the south side, are followed by siliceous flagstones, occasionally used for building, while to the north some of these rocks are used as hone-stones. Nowhere, in short, in all this range, is the limestone placed in a trough by a reversed dip, as in Durness, all the strata being invariably inclined to the E.S.E., whilst the masses lying to the east, though occasionally gneissic, are on the whole very different from the old or fundamental gneiss.

The limestone reappears in its course to the S.S.W. at the head of the Lochs of Glendhu and Glencoul, and thence passes into Assynt, where it again expands, as in Durness, into a mass of considerable thickness, and is there more clearly exposed between masses of quartz than in most parts of its northern range.

*Fossils of the Durness Limestone.*—Mr. Salter has supplied me with the following description of the Organic Remains from the Durness Limestone.

### CEPHALOPODA.

#### Orthoceras mendax, spec. nov. Pl. XIII. fig. 24.

This form comes nearer to Hall's figures of *Orthoceras multicameratum* (Pal. New York, vol. i. pl. 11) than to any other species we are acquainted with; and as the smooth *Orthoceratites* are so difficult to identify, it would have been more satisfactory to me to have left it with that species, than propose a new specific name. But in the adult portion of our shell there is an appearance of annulation, which cannot be altogether due to the state of the fossil, for it is too regular; the younger portion, in an equal state of preservation, appears quite smooth. The contradictory appearances have suggested the name.

General form very gradually tapering, with shallow close annulations ($\frac{1}{8}$th of an inch apart in a diameter of $\frac{3}{4}$ of an inch) in the older portion, in the young nearly smooth. Section circular. Septa numerous, close-set, one to each annulation in the older part; at a diameter of 4 lines there are 15 to an inch. They are only slightly concave, and bent down somewhat angularly* towards the siphuncle, which is excentric, thick, smooth-edged (not at all beaded), and compressed in a direction from front to back. It also has a shallow groove along the side nearest to the centre of the shell, so as to give in section a somewhat bilobed form (fig. 24 *b*).

Specimens from Canada, of what I believe to be *O. multicameratum*, resemble this shell so strongly in the young part, and have so similar a siphuncle, that it is difficult to regard them as different species; they, however, taper more suddenly.

### Orthoceras arcuoliratum, Hall.

(Palæont. New York, vol. i. pl. 42. fig. 7.)

Fragments of this species resemble those from Canada and N. America, with oblique and sinuous rings; and, though imperfect, differ decidedly from other forms accompanying them which have direct annulations, and which I refer to the species next described.

### Orthoceras vertebrale, Hall? Pl. XIII. figs. 22, 23.

(Hall, Palæont. New York, vol. i. pl. 43. fig. 5.)

The specimens are much smaller than those figured by Hall, and have a circular section and central siphuncle when young; the annulations, however, are narrower and more prominent.

One specimen (fig. 22), with very slightly oblique rings, is compressed; it has blunter and broader rings than the other. None of Hall's figures strictly agree with it; but it might be the young state of *O. bilineatum* of that author.

### Orthoceras undulostriatum, Hall. Pl. XIII. figs. 25, 26.

(Palæont. New York, vol. i. pl. 43. fig. 7.)

Although the side-view of Prof. Hall's figure 7 *e* has not the rings quite so oblique as in this specimen, I do not think it a distinct species, for the dorsal view quite agrees, and the rings have about the same degree of convexity, with a slight keel along their middle, more conspicuous in the weathered specimens.

The septa appear to have a sinus on the dorsal surface like that of the rings—a character quite unusual in *Orthoceras*. But the Cephalopoda of this very old Silurian zone present many abnormal characters, such as the extraordinary size of the siphuncular tube, and its being filled up with solid or cellular tabulæ. One of the most singular of all these shells is the species next described, and for which I am obliged to institute a new genus.

* Very much in the way that Hall represents them in his figure of *O. multicameratum*, *op. cit.* pl. 11. fig. 1 *d*.

### PILOCERAS *, gen. nov.

A broad, conical, and slightly curved shell, subcylindrical (or compressed). Siphuncle and septa combined as a series of conical concave septa, which fit into each other sheathwise.

### PILOCERAS INVAGINATUM, spec. nov.

Pl. XIII. figs. 17–21; and Woodcut, fig. 7, *c*.

*P.* 5 uncias longum, conicum, subcurvum, ore ovali, (long. oris ad lat. ut 11–8).

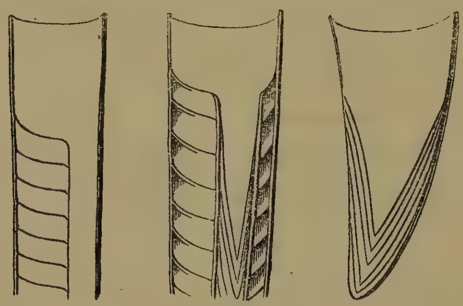
This singular shell, which seems to offer the simplest of all Cephalopodous forms (and to combine in its septal plates both septum and siphuncle), is not unfrequent in the Durness limestone, in a silicified state. None of the several specimens collected by Mr. Peach are perfect.

The mouth is oval, with the longer diameter about 2 inches, and the breadth $1\frac{1}{2}$ inch, in specimens which would measure above 4 inches long. The general form is gently curved, ending in a somewhat obtuse point (fig. 19), near which the tube is annulated rather strongly, while in the older portions it is more faintly so.

The septa, at a diameter of $1\frac{1}{4}$ inch, are rather more than one $\frac{1}{5}$th of an inch apart, and viewed in section (fig. 21) show only three concentric sheaths. There is clear evidence only of four septa in the longitudinal section (fig. 20), the remaining lines being due to the crystallized linings of the chambers. These septa end in a sharp point downwards, the walls meeting at an angle of about 35°, or less.

Comparison is naturally sought for this remarkable genus among the numerous Cephalopods of the same zone. In America the *Orthocerata* with large lateral siphuncles (woodcut, fig. 7, *a*) abound,

Fig. 7.—*Diagram of some forms of Lower Silurian Orthoceratidæ.*



*a* *b* *c*

*a.* Cameroceras. *b.* Endoceras. *c.* Piloceras.

and in some of these the diameter of the siphuncle is so great in proportion to the size of the shell, as almost to realize the form now under consideration. *Endoceras proteiforme*, Hall, Pal. New York, vol. i. pl. 48, &c., and still more *E. magniventrum*, pl. 53, show not only a great siphuncular space, but also a pointed termination of the siphuncle itself (fig. 7, *b*), which thus appears as an elongated lobe or process of the hinder part of the body, like one of the many lobes of

* From πῖλος, *a cap*, and the usual termination κέρας.

the Goniatite or Ammonite, but specialized for a certain end. I had occasion to point out this in a paper on a peculiar Cephalopod, *Tretoceras**, which has, in addition to the ordinary siphuncle, a long posterior lobe extending through *seven* or more of the septa. In some of Hall's figures of *Endoceras* (*op. cit.* pl. 44, for instance, if not in pl. 19), there are indications of a forked or triple termination to the long siphuncular lobe, the cavity behind being filled up by solid deposits. Hence there is an appearance as of one or more *Orthocerata* being contained in the large siphuncle. The fossils called *Hyolites*, in the Silurian rocks of Sweden, are believed to be similar internal casts of siphuncles.

In *Piloceras* the continuity of the hinder part of the body with the siphuncular lobe is complete, and only ordinary septa (not solid masses) are secreted from its surface. There is no appearance of any external shell to which these conical septa might have appertained as a broad siphuncle.

We have then, in this fossil, what I believe to be the simplest form of Cephalopodous shell; and it is very suggestive that it should occur at the base of the Silurian deposits (the lowest in which *Cephalopoda* are known) both in Britain and Canada†, and be accompanied in these beds by genera, like *Endoceras* and *Cameroceras*, which connect it with the ordinary forms of Orthoceratite.

PILOCERAS —— ?

There are not specimens enough to characterize a small species which occurs of this genus, an inch or two long, and of a cylindrical tapering form. The septa are of the same shape as those above described.

ONCOCERAS? Pl. XIII. fig. 27.

The specimens are so imperfect that we cannot tell if the mouth be really much contracted or not, or of what form the apex is. The latter is but slightly curved, and the shell increases gradually and regularly towards the terminal chamber, which is somewhat longer than broad, and appears to be inflated. The septa are concave and oblique, rising highest against the dorsal (shorter) side, and so close together that seven lie in the space of a quarter of an inch. The siphuncle is rather large and external.

The American species, *O. constrictum*, is more curved and more contracted at the mouth, and it has more distant and straighter septa. Our fossil is referred very doubtfully to *Oncoceras*.

## GASTEROPODA.

MACLUREA PEACHII, spec. nov. Pl. XIII. figs. 1–5.

*M.* triuncialis, valde depressa, umbilico latissimo; anfractibus 5–6, infra planatis, supra rotundatis subangulatis; operculo longo spirali.

This fine shell is distinguished immediately from the other known *Maclureæ* by its very flat shape, the discoid whorls scarcely over-

* Quart. Journ. Geol. Soc. vol. xiv. p. 177.

† In the Calciferous Sandrock, Billings (in letter), 1859.

lapping each other at all, and exposing nearly the whole of the great umbilicus* (fig. 2). The whorls on this, the upper, side are convex, subangular a little beyond the middle, and abrupt on the margin of the umbilicus; the width of the last whorl in comparison with the preceding is as 7 to 4. On the lower side (fig. 1*a*) about five are visible; the inner ones are more equal in size, the second being scarcely twice the width of the third. A raised sutural ridge runs round the inner margin, and (unless this be due to pressure) the centre of the whorl is somewhat angular also.

The operculum (figs. 4, 5) is widely different from that of *M. Logani*†, having the nucleus produced in the most extraordinary way, and spirally rolled. The appearance is that of a gasteropod shell (*Capulus* or *Pileopsis*) unrolled; but by comparison with fig. 6, which represents the operculum of *M. Logani*, the corresponding areæ may easily be traced. The lower edge (*a*) is nearly straight, to correspond with the flattened base of the mouth, and the ridges which correspond with the inner angle (*e*) and base (*d*) of the mouth are only very much stronger than in the Canadian species. Coarse rough lines of growth cover the surface, and antiquate the whole of the operculum. The umbo (*b*) is much more produced in some specimens, and incurved in a remarkable degree. All the specimens have the inner process broken away. The chief figure (1*a*) has the operculum added to it in outline (1*b*), to show what position it appears to have occupied in the full-grown shell. Fig. 3 is a restored outline-view, seen edgewise.

The resemblance of *Maclurea* to the genus *Caprotina* or to *Caprinella* will at once be evident; and it was to this group, the *Rudista*, that Mr. Woodward was first inclined to refer the genus. He has, however, included it in the *Heteropoda* as a solid form, probably sedentary, and allied to *Bellerophon*.

### Ophileta compacta. Pl. XIII. fig. 12.

(*O. compacta*, Salter, Decades of the Geol. Survey of Canada, Dec. I. pl. 3.)

As this interesting and very peculiarly-formed shell has been fully described in the work above quoted, the details need not be repeated here. In the Durness limestone it occurs generally of a smaller size than in Canada, though we have one imperfect specimen (not figured) an inch broad. The under side (*a*) is perfectly flat, the upper (*c*) deeply cup-shaped, and the cast of this surface (*b*) is of a dome-like form, with deep notches at the sutures of the whorls.

On a careful comparison I can find no essential difference between the British shell and the Canadian one, except the less rapid growth of the whorls. In a specimen from Beauharnais, near Montreal, $1\frac{1}{4}$ inch wide, the proportion of the last whorl to the preceding is as 3·75 to 2. In one from Durness an inch broad, the propor-

* Not the real umbilicus, as in other shells, but rather the sunk spire (Woodward). The shell is not a reversed one,—the flat side is the under side.

† 'Decades, Canadian Survey,' vol. i. pl. 1. In these figures, as also in our own, the shells are represented in an inverted position—the characters being more easily shown in that way.

tion is 3·25 to 2. This difference is probably in exact accordance with a less favourable nature of the locality, which did not permit of rapid growth or the attainment of full size.

*Ophileta levata*, Vanuxem, besides being a small species, has more numerous whorls, and appears to have a narrower umbilicus.

EUOMPHALUS (MACLUREA) MATUTINUS, Hall?

(Palæont. New York, vol. i. pl. 3. fig. 3.)

Several small specimens in the Durness limestone appear to correspond with the species which accompanies *O. compacta* in Canada; but no stress should be laid on the identification of so obscure a fossil; it may be a representative form only. Another and somewhat larger species is found with it. There is, besides, a large *Raphistoma*, like *R. labiata*, Emmons, and scarcely distinguishable from it.

PLEUROTOMARIA THULE, spec. nov. Pl. XIII. fig. 13.

*P.* vix unciam lata, pyramidata (ad apicem 45°), suturis inconspicuis; carina prominula, angusta, subplana; anfractibus 5–6, striis supra obscuris, infra profundis exaratis; basi subplana, ore rhomboideo.

About five lines high, and the same breadth at base, of a pyramidal shape, the five or six whorls regularly conical, and scarcely distinct at the sutures except by the prominent narrow band. The whorls are nearly smooth above the band, or crossed only by very oblique curved lines of growth; but below the band they are very rough and prominent over the nearly plane base. The band itself is rather prominent, angular above and below, but with no depressions or keels upon its surface; it is crossed by strong arched lines of growth. The mouth appears to be regularly rhomboidal.

Many palæozoic species resemble, yet are not identical with, this shell. It is only necessary to compare it with one allied species, to which at first sight it is likely to be referred, the *P. subconica* of Hall's 'Palæontology,' vol. i. pl. 37. fig. 13. That species, however, as figured, has a much more prominent and rather ventricose base, and is moreover transversely and closely striated, the striæ on the keel being collected into two distinct ridges, which margin the keel and make it almost a double one. There is nothing of this in our species, which has also more numerous whorls. If Hall's figures 8 *d*, 8 *e*, be of the same species, the resemblance is closer; but these are only internal casts; and his fig. 8 *a* is evidently the type specimen.

Four specimens, of which two are figured, occur near Balnakill in Durness.

MURCHISONIA (HORMOTOMA*) GRACILIS, Hall; var. GRACILLIMA. Pl. XIII. figs. 7, 8.

(Palæont. New York, vol. i. pl. 39. fig. 4. *M. angustata*, *op. cit.* pl. 10. fig. 2.)

It is not certain that this form is identical with those given by

* Proposed in 'Decade I., Geol. Survey Canada' for the elongate beaded forms of *Murchisonia*.

Prof. Hall in his volume; but believing, as I do, that both the figures above quoted belong to one species, I do not see enough in the more elongated form of our fossil to induce me to describe it as more than a variety.

In the ventricose and slightly angular whorls there is the closest resemblance; but, if their greater number and the consequent more tapering form of shell be considered as specific, it may retain the name *M. gracillima*, and will stand as a representative species. The length of our largest specimen is 1 inch 4 lines, and in that length there are 14 volutions; in a Canadian one of the same length not above 10 or 11. As we have not the exterior, it is safest to leave it as a variety.

Murchisonia angulocincta, spec. nov. Pl. XIII. figs. 9, 10.

*M.* vix uncialis angustissima, anfractibus numerosis brevibus transversis perangulatis, angulo submediano; ore rotundato.

This is decidedly a different species from the last, and, though imperfect, possesses sufficient external character to allow us to distinguish it by a name.

It is far more elongate than *M. gracilis*, and of more numerous whorls than any species yet described, having, in a length of $\frac{3}{4}$ inch, 13 whorls, all of which are angulated, the upper ones strongly so. The angle is rather below the middle of the whorl, and the upper portion is somewhat concave, while the base is convex beneath it. Mouth rounded. The specimens are much worn.

Murchisonia bellicincta, Hall? Pl. XIII. fig. 11.

(Palæont. New York, vol. i. pl. 39. fig. 1.)

The specimens are too imperfect positively to identify this shell; but the size and proportions are very much like those of Hall's species, especially his figs. 1 *a* to 1 *d*: fig. 1 *e* seems much more elongated.

## BRACHIOPODA.

Orthis striatula, Emmons. Pl. XIII. figs. 14–16.

(*O. testudinaria*, Memoirs Geol. Surv. vol. ii. pt. 1. pl. 27. fig. 8.)

Three specimens only have occurred of this characteristic Llandeilo-flag species. They are of the same size as those in Allumette Island, Canada, and more convex than usual in the species.

## ANNELIDA. Pl. XIII. figs. 28–31.

In the quartz-rock of Durness, beneath the limestone, the abundant annelide-tracks have been already referred to (p. 366 & 368). It is only necessary to explain the figured specimens. Fig. 28 is one of the ordinary vermicular impressions so generally referred to worm-tracks or -burrows. In the present instance this is rendered more likely by the occurrence of some of the matter of the tube itself as a thin glossy film.

Fig. 29 represents a pair of those double burrows which are characteristic of shallow-water deposits through all the Palæozoic series (see fig. 5. p. 368). They are known under the name of *Arenicolites*. Fig. 30 is a side-view of the contents of the burrow, and is trumpet-shaped above and striated on the sides.

Fig. 31. *Serpulites Maccullochii*, new species. (See 'Siluria,' new edit. p. 222.) Short, subconical, and curved tubes, of thick substance, and with but a slender central perforation. They were probably quite free, living in sand as does the recent *Ditrupa*, to which they are not unlike, except in the great thickness of the shell.

ZOOPHYTA.

There are fragments of two Corals—one of the Millepore group, and one probably a cup-coral, but too imperfect to identify; and many of the shells seem to be invested with a Sponge resembling the *Stromatocerium rugosum* of the Canadian rocks.

*Note on the Fossils.*—It will be observable, on glancing over the previous list, that the identifications with American fossils are not in many cases complete—certainly not so much so as a more cursory examination at first induced me to believe. And it may perhaps be that some of those here positively identified with species of the lower limestone of America may prove to be representative forms only when more perfect specimens can be compared. For example, *Orthoceras mendax* merely resembles *O. multicameratum*, Hall. *O. vertebrale* is but a doubtful identification, from imperfect specimens. *Oncoceras*, though of a different species, is an American genus. *Euomphalus matutinus* and *Raphistoma labiata*, if not identical, are at all events representative forms. *Maclurea Peachii*, *Murchisonia angulo-cincta*, and *Pleurotomaria Thule*, though new species, are closely allied to American forms.

On the other hand, there appear to be some, of the identification of which there cannot be much doubt: such as *Orthoceras arcuoliratum*, Hall. *O. undulostriatum* of our lists differs very little from the species so called. *Orthis striatula* is truly identical. *Ophileta compacta* and *Murchisonia gracilis*, with *M. bellicincta*, are others which I cannot separate from American species.

There are, then, *five identical*, three doubtful, four which may fairly be called representative forms (the *Maclurea*, the *Orthoceras*, *Murchisonia angulo-cincta*, and *Pleurotomaria*); and *Piloceras* is a new genus, found in Canada* and in Scotland.

That this truly North American assemblage should be found in the extreme north of Scotland, on the same parallel as the Canadian, —that species of *Maclurea* and *Raphistoma*, resembling those of the St. Lawrence basin, and *Orthocerata* bearing large siphuncles like those of N. America, Scandinavia, and Russia, should occur in Scotland, and yet be scarcely known further south, is at least suggestive of a geographical distribution—perhaps even of climatal conditions —not very unlike that of more modern times†.—J. W. S.

* The Canadian species is distinct.

† See the generalizations on this head, 'Siluria,' new edit. pp. 182, 507, *et seq.*; and Appendix, p. 553.

*Overlying Micaceous Flagstones and Younger Gneiss.*—In the masses which overlie the quartz-rocks and limestone, we no longer find the same uniformity of lithological composition as in the lower strata. In the earlier deposit, mica is absent; but in the higher masses, that mineral begins to prevail. Here and there, as we leave Assynt and Durness, and proceed to the E.S.E., it occurs in otherwise pure light-grey and whitish quartz-rock, and at others in dark-grey micaceous schists. Independently of dislocations and partial axes of elevation (one of which has been described as seen between Durin and Rispond, whilst another is met with at the south-eastern end of Loch Eribol, where granite protrudes), the micaceous part of the quartzose series is observed to be superposed, as a whole, to the group in which the limestones and their fossils occur. From Loch Eribol the strata have a persistent dip to the east by south. (See Section, fig. 8.)

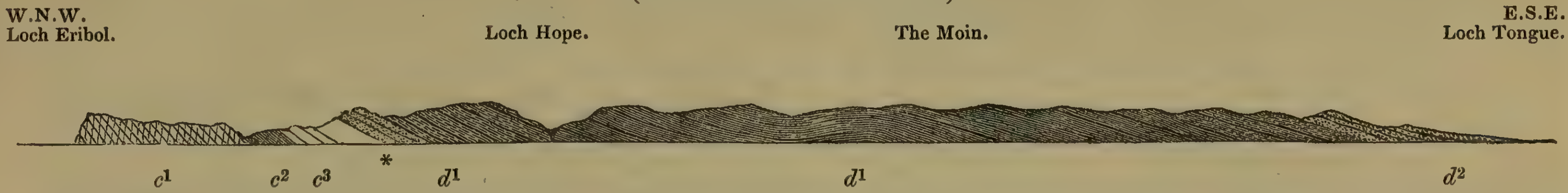
From the western coast-cliffs of Cape Wrath to the bay called the Kyles of Tongue, there can, indeed, be no sort of doubt that the whole series of quartzose and calcareous rocks which overlie the older gneiss and the Cambrian conglomerates, are, in their turn, covered by the younger micaceous flagstones of Inverhope and the Moin, and constitute one great series, the age of which is determined both by the order of superposition and by the fossils contained in one of its lower members.

It is still, however, necessary to call special attention to the upper portion of this group, which, though here and there a quartzose flagstone, also contains chloritic and micaceous schists, and occasionally exhibits so complete a mineral transition into a gneiss, that Macculloch in his map of Scotland, and after him Cunningham, grouped under one name the whole of these superior masses, as well as the great masses now shown to lie below the Cambrian and Lower Silurian rocks. In examining this country in the year 1827, my companion (Sedgwick) and myself distinctly noted both chloritic schist and flat thin-bedded gneiss as occupying several parts of the country, which we walked over in two directions, in the interior of this part of Sutherland; and we had no doubt that such rocks lay far above the limestones of Assynt. That careful and laborious observer, Cunningham, who examined the same tract after a long interval, took the same view. These same overlying rocks are continued, with some undulations, from the parallel of Tongue, on the coast, and Ben Clibrig, Lord Reay's Table, and Alt na Harrow, in the interior, to the frontiers of Caithness and Ross-shire on the E. and S.E.*

Usually thin-bedded and micaceous, they are formed, in certain places, of alternations of greenish- and greyish-coloured micaceous or quartzose gneiss, which present the external aspect of the Italian "Cipollino" or "onion-coated." Such rocks are seen at the escarpment of Ben Hope, in the heart of Sutherland, where they still dip

* The mountainous fringe extending from near Strathy on the north to Tomentoul on the south has not yet been examined by me; and I must abstain from including it in the same category; for it is by no means impossible that the older gneiss or fundamental rock of the N.W. may there be brought out again.

Fig. 8.—*Section of the Quartz-rocks, Limestones, and overlying Gneissose rocks, between Loch Eribol and Loch Tongue.* (Distance about 10 miles.)




$c^1$. Lower Silurian quartz-rock, with *Annelides*. $c^2$. Limestone. $c^3$. White quartz-rock, capping limestone. $d^1$. Micaceous, gneissose, and chloritic schists, passing upwards (on the banks of Loch Tongue) into whitish micaceous flagstones, $d^2$.

[At the point in this Section which is marked by an asterisk, my friend Professor Nicol, who has revisited Sutherland this spring, has satisfied himself of the existence of a band of porphyry, occurring between the limestones and quartz-rocks which I have shown to be of Lower Silurian age and those varieties of schistose rocks, lying to the east, which I consider to be overlying, but which Prof. Nicol does not separate as a whole from the underlying gneiss. Though I have not yet seen the porphyry in question on the east side of Loch Eribol, I am aware of the existence of eruptive granitic rocks in about that position near the southern end of the Loch, and have also examined other eruptive rocks (syenite and porphyry) to the east of the calcareous and quartzose (Lower Silurian) rocks of Loch Assynt. Not doubting the accuracy of the mineralogical and physical observations of my able contemporary, I do not yet admit that the intercalation of any rock whatever of igneous origin can be brought forward as a reason for setting aside my facts and inferences as to the general order by which the crystalline rocks to the east of such dislocation overlie and are distinct in age from all the rocks which occupy the North-west coast of the Highlands. I have long ago been convinced that the general classification of deposits must be made, to a great extent, independent of all local phenomena of eruption and dislocation. Thus, in Wales, for example, there occur many extensive distortions along given lines, by which the Silurian strata are powerfully affected and dislocated without their general order of superposition being invalidated, whilst conformable masses of igneous origin are still more extensive. So in the Highlands, as explained in this memoir, a porphyry is intercalated between the fundamental gneiss and the Cambrian sandstone. In Durness the Lower Silurian limestone itself is penetrated by greenstone and serpentinous rocks. Then we have eruptive matter above the Lower Silurian limestones and quartz-rocks; whilst other eruptive rocks, whether porphyry, granite, or syenite, are seen to rise through that which I consider to be the overlying series at various horizons. With my present views, therefore, I see no reason whatever to alter my inferences; but, as I propose to revisit the North-west coast of Scotland during this summer, I hope to state the results at the ensuing Meeting of the British Association at Aberdeen. In the meantime, the reader will find in the various diagrams of the late Mr. Cunningham, who explored the north-west of Sutherland more in detail than any modern geologist, several sections showing an overlying gneiss conformable to the subjacent quartz-rocks and limestone, and wholly discordant to the inferior or fundamental gneiss. See "Geognosy of Sutherland," in the 'Trans. Highland Society of Scotland,' vol. xiii.—July 1, 1859.]

to the E.S.E., and contain garnets, whilst the lower part of the very same mountain is a true quartz-rock.

To the east of Tongue there is indeed a great sameness of such crystalline strata, which are inclined at low angles of not more than 10° or 12°; but at Naver the micaceous quartzose flags with garnets dip 60°, and at Farr as much as 70°. Thenceforward, in travelling eastward, intruding bosses of a granite similar to that noticed by Nicol and myself at the head of Loch Eribol again prevail; and some of these (as formerly described by Sedgwick and myself) not only penetrate the crystalline strata, but also throw off the overlapping Old Red Sandstone and Caithness Flags.

In Caithness the explorer enters into a region of essentially different structure, and consequently of an entirely different outline. In the very first quarries of the overlying sandstones and flagstones which he reaches, the traveller finds no longer a S.E. or E.S.E. dip, but one to the N. or N.W., or athwart the older rocky series on which he has been wandering. When the quartzo-gneissose series is followed southwards, by Ben na Ghream along the western flank of the flat and monotonous county of Caithness, we come to that remarkable group of mountains called the Scarabins, which are obviously a portion of the upper member of the same crystalline series. Here crystalline quartz-rock prevails, weathering pure white, and of a different character from the quartz-rocks of the west, being probably the result of the intrusion of the great masses of granite which there abound.

The manner in which the base of the Old Red Sandstone overlaps these quartz-rocks was long ago described by Sedgwick and myself*. All around the Scarabins, and particularly to the east of Berridale, the most striking discordance is seen in the relative strike and dip of these two groups,—the quartz-rock, or associated gneissose strata, being inclined sharply to the W.S.W., or to the south by east, whilst the Old Red conglomerate and sandstone dip away east and north, and also to the west, at 10° and 12° only.

In like manner, when we proceed on the true dip of the older rocks from Loch Assynt on the W.N.W., and follow the course of the Oikel River from Sutherland into Ross, we meet with a great rupture and a complete unconformity of stratification at the junction with the Old Red Sandstone. Hence, setting aside partial disturbances at various horizons, as resulting from the eruption of igneous rocks, we see that all the crystalline and subcrystalline strata from the west up to this great and general break, and which are intercalated between the Cambrian Conglomerates beneath and the true Old Red Sandstone above, must belong to one and the same great natural division; for they are, on the whole, conformable to each other in their strike, undulations, and inclination. Even if no fossils had been found in them, it was probable that, being placed between a conglomerate of very high antiquity, on the lower or western side, and the base of the Old Red Sandstone on the other, these quartzose

* See Trans. Geol. Soc. 2nd ser. vol. iii. p. 128.

rocks, limestones, mica-schists, &c., would probably prove to be of Silurian age. Fortunately the discoveries of Mr. C. Peach have conclusively settled that question as respects one of their lower members.

A few observations are, however, called for in reference to a difficulty which has presented itself to the mind of Professor Nicol. Admitting, as he now does, that the quartzite group (which, from mineral qualities, he had suggested might be of Carboniferous age), is, as I supposed, Lower Silurian, he still doubts whether that group really passes under the micaceous flaggy rock or eastern gneiss. His doubts have been increased by finding, that along the line of junction there occur (particularly in the west of Ross-shire, at the head of Loch Maree) outbursts of igneous rock which he thinks are connected with a general dislocation along the strike.

But my observations do not support this view. See fig. 8 and its appended Note.

Such protrusions of igneous rock occur very irregularly in the North-western Highlands and at various horizons. Thus we have seen that in Canisp porphyry is associated with the lowest part of the Cambrian rocks; that hypersthenic rocks penetrate the limestones of Durness and the quartz-rocks and limestones of Assynt; that syenite and felspar-rocks again reappear above the Silurian limestones at Ledmore and on the banks of Loch Borrolan; whilst the powerful eruptive syenitic mass of Ben Laoghal penetrates the younger gneiss in the heart of Sutherland. Such eruptions do not, therefore, in any way specially cut off the fossiliferous Lower Silurian zone, but burst through overlying strata of different ages.

Compared, indeed, with the wide range of the stratified crystalline rocks, these eruptive or igneous masses are mere pustules, which in no wise derange the general succession, though they occasion partial rolls and folds of the beds near the points of local intrusion. Thus, in advancing to the S.E. from Assynt, we have no sooner passed the boss of syenite near Loch Borrolan and the inn of Alt-na-Gallagach, towards the E.S.E., than we are presented with the very same flaggy micaceous succession which is so clearly exposed between Lochs Eribol and Tongue. The eruptive matter is indeed very likely to peer out here and there along the lines of least resistance, or where one set of beds is overlaid by another.

On the high road leading from the west to Lairg and the Dornoch Firth, a limestone which I consider to be superior to any of the Assynt rocks is exposed at Cnoc Craigie *. Though affording no fossils under our hasty inspection, this rock, which is yellow and apparently dolomitic, clearly overlies all the light-coloured quartzite series, and is at once surmounted by dark-grey micaceous flagstones quite unlike any stratum beneath them. At the Bridge of Alt Ellag,

* I was informed, by a very intelligent man who had accompanied the Surveyor who made the map of Sutherland, that the limestone of Cnoc Craigie reappears to the N.N.E. at Kinloch Ailsh and Fianloch More, at the west end of Loch Shin; and that freestone reoccurs in this flag-like series at Ben Skillachor, north of Loch Griam.

at Loch Craigie, and again at Lub-croy, these flaggy micaceous rocks are well exposed, at the last-mentioned place assuming a gneissose aspect. They are all perfectly conformable, all dipping steadily to the S.E. or E.S.E., and are completely distinct, even in mineral characters, from any of the underlying rocks, whether old gneiss, Cambrian, or the quartzose and calcareous Lower Silurian group. They are, in short, dark micaceous flagstones, which to the N.N.E. range across the upper end of Loch Shin, and thence in the same direction extend to Ben Hope until they occupy the expanse of country between Lochs Eribol and Tongue. See fig. 8, p. 383.

If the banks of the Oikel be descended until that river falls into its marine estuary at Bonar Bridge, the succession of overlying and conformable micaceous and other flagstones is equally clear until we reach the edge of the true Old Red Sandstone of the east coast, the conglomerate base of which is formed out of the debris of all the rocks hitherto adverted to.

If, however, the line of section be deflected from the Oikel a little to the N.E. towards Lairg and the south-eastern end of Loch Shin, then, the overlying flagstone and micaceous series being intruded upon by vast masses of granite of posterior date, the depository beds are so altered, veined, and fractured as to be made to resemble in some respects the old gneiss of the west coast. But these are local exceptions; for the observer has only to remove to a little distance from the edge of the eruptive granite, to the S.E., and he again finds himself in the same flaggy micaceous series as before,—all the beds dipping to the S.E. and E.S.E. The amount of metamorphism produced upon these micaceous and quartzose flagstones, when they have been most affected, is nowhere better exemplified than where they wrap round the granitic and felspathic rocks of the Ord of Caithness and the adjacent tracts, and where many beds constitute a sort of gneiss, and others form, as before said, the completely metamorphosed and crystalline quartz-rock of the Scarabin Hills (p. 384).

Unwilling to generalize too far upon this point (for I have already said that there may be many tracts where the oldest gneiss rises to the surface), I may, however, express my present belief that these micaceous flagstones (often used indeed as roofing-slates, though none of them are affected by a true slaty cleavage), which constitute the edge of the so-called primary rocks of Ross-shire, and thence range into Inverness, Nairn, Moray, and Banff, are parts of a series younger than the fossiliferous Lower Silurian rocks of the west of Sutherland.

If it be objected that the great thickness of these masses offer difficulties in the way of recognizing them to be equivalents of Silurian rocks, I would reply that we have by no means proved that all such beds are to be considered as successive, since the micaceous flags may have been deposits in the same sea, but at some distance from the bottom rocks; and though apparently overlying them, may have been of almost contemporaneous formation, their subsequent elevation and crystallization giving to them the appearance of a distinct superposition.

Then, again, there may be many curvatures, breaks, and repetitions which I was unable to observe. One considerable fold I did indeed notice in the heart of Ross-shire, in the mountain of Aigean on Loch Faunich, where thinly laminated beds of hard grey quartzose gneiss have a reversed dip to the W.N.W., whilst the country to the east around Loch Luichart is much faulted and broken up.

But, whilst I adhere to the belief that the great mass of the micaceous flag-like and younger gneissose rocks, which succeed on the east, are of more recent age than the quartz-rocks and fossiliferous limestones of the north-west of Sutherland, I repeat that the genuine old gneiss may be brought to the surface in many places in the interior, and even on the east coast, in parts of Banff and Aberdeen. Such points may be left for future labourers to determine. In the mean time I believe that the so-called gneiss of the Sutors of Cromarty, and the rocks extending southwards to Flowerburn, Kincordy, and Rosemarkie near Fortrose, on the east coast of Ross, are simply members of a flagstone series which has been much altered by the intrusion of huge granitic and felspathic veinstones. Fine examples of the conversion of these rocks, in various states of change from an earthy flagstone and shale into a crystalline gneiss, are seen in the cuttings of the new high road which descends from the Old Red Sandstone of the Black Isle down to Rosemarkie, whilst the eruptive rock of compact felspar protrudes in deep-red bosses on the shore at Kincordy and rises into the altered and gneissose hill of Larny to the south of Ethie. The same eruptive felspathic rock, similar to one at Helmsdale, which passes into the granite of the Ord of Caithness, occupies a wooded coast-ridge between Fortrose and Avoch, and throws off the Old Red Sandstone, at a high angle, towards the interior of the Black Isle.

It is obvious, therefore, that the former mineralogical classification of rocks, whereby all these strata, of such very different ages, were merged with the same family as the Old Gneiss which lies beneath vast thicknesses of rocks now known to be of Cambrian and Silurian age, has been highly detrimental to the progress of sound geological science.

*The Crystalline Stratified Rocks of other parts of the Highlands compared with those of Sutherland.*—It is not in my power to describe in detail the relations of all the stratified crystalline rocks of the Highlands, though I have traversed their chief masses on many parallels. I presume, however, that the same order of succession as in Sutherland may be applied to the stratified crystalline rocks in the west of Ross-shire and Inverness-shire, which occupy the same place in the general series. Thus, when we extend our examination southwards from Sutherland and Ross on the west coast, we find, on entering into any of the numerous bays or marine lochs which indent the coast from Loch Broom to Loch Duich, which is on the edge of Inverness-shire, that quartzose, micaceous, and chloritic rocks, with limestones in their lower members, are successively exhibited,—the whole having a dominant strike from N.N.W. to E.S.E., and all having a prevalent inclination to the E.S.E.

Professor Nicol has already shown how, in many places, such rocks overlie the older conglomerates and sandstones, which I consider to be of Cambrian age. The only marked distinctive change in the mineral character of these stratified rocks as they range southwards is, that the quartzose or purely siliceous character is not so dominant as in Sutherland and the north-western parts of Ross-shire, the arid, bare, whitened surface of the weathered quartz-rock being no longer dominant. Thus, in the headlands between Loch Kishorn and Loch Carron, the range of bedded limestone is seen, just as in Assynt and Durness, to possess the same joints and oblique rude cleavage, whilst the conformably overlying series consists of a variety of quartzose and chloritic beds, some of pinkish, others of grey colours, and some containing mica and asbestos,—the whole being clearly overlaid by a clay-slate, which ranges down to the shore of Loch Carron.

If we make our observations in a more southern parallel, and pass across Ross-shire from Lochalsh and Kintail on the west to the Old Red Sandstone frontier on the east, the general succession is the same, though there are considerable changes of lithological character when the same rocks are followed southwards or S.S.W. upon their strike. On the south side of Loch Duich, which affords an excellent transverse section, some of the calcareous bands of highly crystalline limestone are white, whilst others are chloritic and greenish and much resemble the Connemara marble of Ireland,—such bands being finely intercalated either in micaceous flagstones in parts calcareous, or in finely laminated slaty flagstones which pass into a rock which must be called gneiss, as it has layers of quartz, felspar, and some mica. Points of syenite protrude here and there, and diversify the projecting rocky bosses. Now, although the prevalent dip of all the strata near Totig is to the E.S.E., we see, in ascending to Inverinat, great flexures, by which the strata, curved at high angles, give their exquisitely beautiful and conical outlines to the mountains in which Loch Duich is embosomed.

At the head of Loch Duich, however, near Inverinat, the dip to the E.S.E. is resumed, at an angle of about 25°, which angle increases to 50°, 60°, and 70° as you proceed eastward through the lofty and rugged defile called the Bealloch of Kintail. There the peaks which form the steep watershed of the north-west of Scotland (in a part of which the splendid Falls of Glomach occur, where the water cascades over a lofty precipice, and not distant more than three or four miles from the salt-water bays) are composed of the same flag-like pinkish quartzose gneiss, the beds of which are seen to be finally thrown off to the E.S.E., thus clearly overlying the limestone and other masses which occupy the shores of Loch Duich.

In pursuing the mountain-track through the Bealloch of Kintail to the head of Loch Affric, I found that, in descending on the long sloping moorlands by which the waters glide away to the east, the stratified masses become more horizontal, with occasional undulations,—so that very much the same class of quartzose rocks is continued very far eastwards, their bare stony summits constituting the favourite resort of ptarmigan, their slopes the haunt of deer, and their valleys the breeding-grounds of grouse. The undulations of such rocks are well exposed where the principal feede of Loch Affric escapes from the higher moorlands into that fine sheet of fresh water from the highlands of Kintail, and at a pass and ford called "Aa na Mullich *."

I further believe that the regularly-bedded limestones, which are intercalated in the chloritic and quartzose rocks of Dumbartonshire, and are seen on both banks of Loch Fyne, and also in terraces to the north and west of Inverary, may be classed with some of the oldest of those stratified masses which, like the limestones of Sutherland, are unquestionably of Lower Silurian age. For these calcareous bands also pass under vast masses of mica-schist and quartzose-gneissic rocks. Moreover, as one who has explored the wilds of the Breadalbane deer-forests, I think that the vast expanses of quartziferous flagstones, mica-schists, &c., are simply the prolongations of those rocks of the North-western Highlands, which have here been treated of. Undulating at slight angles of inclination through Glen Orchy, and clasping round the granite of Ben Cruachan on the one hand, or pierced by the porphyries of Glencoe on the other, these flag-like strata, occasionally passing upwards into clay-slate, extend to the S.E. in broad curves, over the region of the Moor of Rannoch, and around the Black Mount; whilst along the banks of Loch Tay they contain regularly-bedded limestones, which in their turn dip to the S.E. under other schistose rocks.

In following them to their south-eastern frontier in Dumbartonshire, where these rocks, terminating upwards in clay-slates, are surmounted by the Old Red conglomerate and sandstone, we may indeed speculate upon the unfolding in such tracts of the equivalents of younger and higher strata than any which are observed in the northern counties. Thus, the chloritic schists of Ben Lomond, containing pebble-beds which underlie the clay-slates, may prove to be the equivalents of some of the Silurian conglomerates of the S.W. coast of Scotland. Let us hope that the day may come when fossils will be discovered in some of those regularly-stratified masses of such varied lithological composition, and thus enable us to speak of their age with the same decision which has been applied to the crystalline strata of the west of Sutherland.

Looking at the Highlands as a whole, it is essential to observe that, in proceeding from north to south, the geologist meets with vastly larger masses of intrusive rock than in the typical tract of Sutherland. Thus, the edges of the huge granitic Grampians, alone,

* I hope that my Highland pride may be pardoned if I attach great interest to this gorge, seeing that my ancestor Colonel Donald Murchison (whose brother, my great grandfather, was killed at the battle of Sheriff Muir) selected it as the spot where, in the year 1716, he so placed the native Highlanders under his command, all of them Jacobites, as well as their chief, the exiled William Earl of Seaforth, whose lands he was defending, that he successfully resisted and beat back the troops of George I., who in vain endeavoured to take possession of Kintail; and hence these mountains were held for their noble owner, who was eventually pardoned. I live in the hope that my eminent friend Sir Edwin Landseer will soon fulfil his promise, and gratify me by producing a painting of this scene, the history of which is well known to all old Ross-shire Highlanders.

call for a separate historian, who shall describe the nature, and, if possible, fix the age, of all the successive coats of the older crystalline rocks which are folded around that vast igneous nucleus, just as Colonel Imrie did in reference to one transverse gorge, which he laid open so admirably forty years ago. We have yet to ascertain the exact relations of the uppermost clay-slate of Forfarshire to the overlying Arbroath flagstone, which must be considered the base of the Old Red Sandstone of that tract. With the expansion of the older stratified crystalline rocks as they fold over to the S.E., it must be borne in mind that there are numerous centres of eruption, such as that, for example, of Ben Cruachan, in Argyllshire, and other mountains to the south and east of it, which penetrate and throw off the stratified masses into various undulations. Other anticlinals and synclinals occur without any such apparent motive cause, as in the clear and unambiguous section of Loch Eck, in Argyllshire, to which I formerly called attention*, and where a vast mass of gneissose mica-schist is seen to rise from beneath the chloritic schists and limestones of Loch Fyne. When the geological surveyors shall be provided with accurate maps, I trust that all these stratified masses of the crystalline rocks of the Highlands will have their true relative places assigned them. In the mean time much may be done, not only in the endeavour to rival Mr. Peach in detecting fossils, but also in the effort to coordinate the fractures which these stratified masses have undergone, and to read off the periods when numerous fissures were made,—the one set longitudinally, or along the strike of the beds as seen in Loch Ness and the line of lakes of the Caledonian Canal—the other transverse, or across the strata, of which the North-western Highlands offer many striking examples, to some of which allusion has already been made.

I cannot attempt to describe all the lithological variations in the rocks which I believe to be the geological equivalents of the crystalline rocks of the N.W. Highlands, in the counties of Aberdeen, Banff, &c. From what I saw, however, in former years, of the thin micaceous flag-stones and clay-slates, &c. of those tracts, I have little doubt that they belong to the same series as that now under consideration. The granitic mountain of Ben na Chie, which I then examined, seemed to me to have performed precisely the same eruptive part in the east as Ben Cruachan in the west, perforating stratified sedimentary rocks, and producing much alteration in them near the points of contact.

The general view of the succession here offered must, however, be alone tested by traversing the northernmost counties from N.W. to S.E., and by marking the manner in which one group succeeds the other. In such examinations, a great number of dislocations like that which has been noticed in Suilven of Assynt, and numerous anticlinals and synclinals, with outbursts of igneous rocks, will doubtless be detected, by which, and by parallel upheavals, the same set of beds will be found to have been frequently repeated between the two coasts.

* Quart. Journ. Geol. Soc. vol. vii. p. 169.

The great physical fact, however, in respect to the series of crystalline rocks in Sutherland, is, that their *lower* members contain those limestones in which organic remains have been found, and that large masses of chloritic, micaceous, and gneissic flagstones, clay-slates, and schists are so superposed, that little doubt can remain that they are also of Silurian age. Allowing for many undulations and repetitions, I see no reason for believing that those overlying crystalline masses are of much greater thickness than the Lower Silurian rocks of Wales and the adjacent English counties.

Having no evidence of the existence of other fossil remains which should indicate the presence of Upper Silurian rocks, and seeing how poorly such strata are developed even in that part of the south of Scotland (Ayrshire) where the Lower Silurians are so rich in fossils, my inference is that the younger members of the Silurian system have never been deposited in the far north. There, a great upheaval of the Lower Silurian, or the quartzo-gneissose series in question, separates it sharply from the Old Red Sandstone, which overlaps it in entire unconformity,—this great break accounting for the nonexistence of any representatives of the Upper Silurian rocks.

It is unnecessary that I should continue to combat, as I did at the last Glasgow Meeting of the British Association, the theoretical idea that the varying and alternating mineral layers of the rocks I have been describing are lines of cleavage or lamination as distinguished from true stratification; since that view can, I presume, no longer have any supporters. In considering these rocks as regularly stratified deposits of different mineral matters, I simply adopted the opinion of all my eminent precursors since the days when Hall and Playfair classed them as metamorphosed sediments. Not only have we examples of coarse grits and sandstones throughout them, but even when we follow them to the south we find regular beds of pebbles intercalated in such chloritic and micaceous schists. In short, they present all the signs by which truly stratified aqueous deposits are defined, not only in their successive mineral layers, but also in having wavy bands of schist interpolated among sandy beds, and the whole being affected by symmetrical joints.

The presence of organic remains was alone wanting to complete the natural inference which I suggested in 1854, that many of the stratified crystalline rocks of the Highlands are simply the metamorphosed equivalents of the Lower Silurian rocks of the south of Scotland.

*Crystalline Rocks of the Shetland Isles.*—My voyage from point to point of the Shetland Islands was much too rapid to enable me to connect all their different rock-masses with those of the mainland. I may, however, suggest that some of the northernmost crystalline stratified masses of Unst, extending out to the small islet called the Muckle Flugga, on which the most northern lighthouse is built, most probably belong on the whole to the younger gneiss and flagstone series.

There may, however, exist, on the western shores of the mainland (which I did not visit), some representatives of the older gneiss.

The most remarkable exhibition of the flaglike gneiss with a persistent and uniform dip is seen on the western cliffs of the island of Unst, where the strata, in precipitous cliffs 200 to 300 feet high, succeed each other rapidly at angles of about 45°. In the Burra Fiord of the same island, granite prevails in strong veinstones, as also in the islets called the Burra Fiord Holms. It is on the outermost of these bosses of barren gneiss that the new lighthouse was erected during the recent Russian War; the summit of the rock is 230 feet above the sea, and exposed to the lashings of the wild Northern Ocean. This rock (named the Muckle Flugga, to distinguish it from a more southern boss, the Little Flugga), with the exception of a small rock called the Out Stack, is the northernmost point of land in Her Majesty's dominions, and certainly the most northern inhabited spot; it is very nearly on the 61° of N. lat.

The rock, up the steep face of which 250 steps are cut, by which we ascended to the lighthouse, consists of sharply inclined shelving masses of gneissose, micaceous, and quartzose flagstones, with some garnets: it is penetrated by many veins of granite. The strata, like those of Unst, dip E.S.E. about 45°, and are all perfectly parallel,—a circumstance the more to be wondered at when it is seen that from Somburgh Head on the extreme south to the Muckle Flugga on the extreme north of the whole group, the prevalent strike and dip are preserved for a distance of eighty miles.

In Balta Sound a visit was made to the mines of chromate of iron, much opened out and extended of late years. This mineral occurs in serpentine rocks with bosses of pure greenstone. Following up certain veinstones on the surface from the north side of the Fiord between Swenee Ness and Buness, the mineral has been found to expand into a large stockwork, about one mile from the shore: the chief direction of the mineral mass is from W.S.W. to E.N.E. There the rock is cut into to a depth of about 86 feet, without detecting any deterioration or diminution of the chromate in the floor of the quarry, which is from forty to fifty feet wide. This mineral mass hades to the north at an angle of from 70° to 80°, and is situated on the hill called Keen Hill, and at the foot of the higher rocky hills called Heysags, which stand out so boldly, overlooking Haroldswick Bay.

The other tract where I had an opportunity of studying the crystalline rocks, was at the Out Skerries of Whalsey, that very singular group of low, rugged islets, chiefly composed of gneiss with granite-veins, but containing one strong band of limestone. It is on the most eastern of these rocks, or the Bound Skerry, that a new lighthouse has been just erected, to exceed in power that of the adjacent Gruna Light*.

Mr. Stevenson here called my attention to the manifest proofs of

* After passing the afternoon upon the rocks, or in admiring the new mechanical contrivances in the lanterns of the lighthouse, we steamed out to the north about ten miles in the dark, to test the effect of one of the improvements made by our companion, Mr. Stevenson, when it was perceptible to all of us that the new light was very superior to the old one on the adjacent rock of Gruna, in the grander and more pyramidal flashes which it gave out.

the remarkable power of the sea-waves when lashing upon this exposed spot in great storms.

The seaward or north-eastern face of these gneissose rocks sloping upwards presents the most chaotic aspect, being covered with clusters of large angular blocks—one of the largest of these being perched at nearly seventy feet above the sea. Now all of them have been torn out of their beds, and most of them moved up-hill for a considerable number of feet, to within a few yards of the base of the new lighthouse. For my own part, I was at first incredulous as to the mode of producing what my lamented friend Leopold von Buch would have called a true "Felsen Meer;" but when Mr. Stevenson brought the data before me, it was quite evident that the sea had done it all. Thus, an inhabitant pointed out some of the chief blocks, several of them of many tons weight, which in a great storm some years back had been moved upwards on the incline fifteen to twenty feet, to heights of fifty feet above the sea. These in their upward translation had scored the rocks over which they passed, just as the stones held in a glacier groove and scratch in their descent; and the freshness of the markings was quite striking. Not trusting to histories of the past, and for a moment doubting even the clear evidence offered by the scoring of the rugged subjacent rock, I interrogated an intelligent under-officer of the lighthouse, who had been two years on the spot, and ascertained that even in the preceding winter, and when the new lighthouse was in course of construction, a huge mass of stone near the sea-level, of which he showed the very bed out of which it had been lifted, had been wrenched out of it and moved up an incline of 10° or 12° to a distance of sixteen feet!—and with this proof all scepticism vanished.

Lastly, perceiving a singular cavernous chasm into which the waves hurl up fragments of rock varying from a few inches to two yards in width to a height of fifty or sixty feet above the sea, I found that, being there confined as in a gullet, they are continually agitated and rolled about in every great storm until most of them are as much *rounded* and water-worn as if they were part of an ordinary sea-beach, before they are shot out to the other side of the chasm.

*Old Red Sandstone of the North-east of Scotland.*—Let us now take a rapid review of the character, dimensions, and fossil contents of the Old Red Sandstone of the North-eastern parts of Scotland, where in the year 1827 the separate masses were described by Sedgwick and myself as offering the fullest and best types of a series which we have since shown to constitute a natural group, the equivalent of the Devonian rocks of other countries. This review is the more called for now that we know the precise geological relations of the base of the Old Red Sandstone of England to the Upper Silurian rocks on which it rests. It is also necessary to point out some features in the successive distribution of its animal remains in the latter tracts and in the central counties of Scotland, when compared with that northern development to which attention is now particularly directed, and to show that the ichthyolitic flags of

Fig. 9.—*General Section of the Old Red Sandstone of the North-east of Scotland.* (From 'Siluria,' new edit. p. 280.)


*a.* Old Red conglomerate. *b.* Red sandstone. *c.* Thin-bedded sandstone passing into flagstones. *d.* Bituminous schists and hard flagstones, with limestones, &c. *e.* Upper Old Red. (*g.* Granite. *q.* Quartz-rock and mica-schist.)

Caithness are not the lower members of the Old Red Series, as previously stated in geological works.

The Old Red Sandstone, in the extended sense of the term, is not what some geologists, who have never examined the North-east of Scotland and the Orkney Islands, have considered it, a small and unimportant formation, the upper part of which might be classed with the Carboniferous deposits, and the rest as of no greater importance as to the time occupied in its formation than a mere fragment of the Devonian group only. On the contrary, the Old Red group of this northern region is a grand and expanded series of very diversified mineral character, which, both from dimensions and organic remains, must be considered a full and adequate equivalent of all the Devonian rocks of South Britain, Germany, Russia, France, Spain, and Turkey. The group as seen in Caithness and the Orkney Islands is composed of three parts—

1. Lower red conglomerate and sandstones.
2. Grey and dark-coloured flagstones and schists, in parts both bituminous and calcareous.
3. Upper red and yellow sandstones.

The annexed general section (fig. 9) exhibits this order.

*Lower Old Red.*—The lower red conglomerate and sandstone (*a*, *b*, *c*) form the external and unconformable eastern fringe of all the stratified crystalline rocks which have been described. Whether the latter consist of quartzose gneiss at Strathy Head on the north shore, or be followed inland along an irregular boundary by Ben Ghream until they become the thin-bedded quartz-rocks of the Scarabin Hills, or consist of granite at the Ord of Caithness, or of gneissose micaceous schists as they range from Sutherland into Ross-shire and there occupy the heights of Wyvis or fold round the lower country of Easter Ross by Dingwall, Brahan Castle, and Fairburn Tower, until they enter Inverness-shire above Beauley, we see everywhere similar rock-relations. Throughout all this tortuous line, the lowest member of the great group under consideration is compounded out of the contiguous and subjacent rocks,—the derivative beds having always a strike and dip different from those of their parent crystalline rocks; any approach to an agreement in their relations being local and accidental. Allusion has already been made to the great change observable in the outline and aspect of the country when we pass from the one to the other group of rocks; and it is useless to enumerate the numberless cases which have fallen under my own observation, where the younger deposit overlies in slightly inclined layers the highly inclined crystalline strata, which, together with an occasional boss of granite or syenite, have invariably afforded the materials out of which the Old Red strata have been composed.

Describing some striking examples of the lower conglomerate, we shall see how it passes up gradually into the Caithness Flagstones.

On the east coast of Caithness, inclined both to the west and east, the Old Red conglomerate and sandstone clasp round the quartz-rocks of the Scarabin Hills. When adjacent to the quartz-rock, the Old Red conglomerate abounds in its fragments; but on the east and south of Braemore, granite and gneiss are added to the débris. I ascertained, by passing along the summits of the rugged Scarabin Hills, that the Old Red conglomerate is there almost entirely compounded out of the white quartz-rock on which it rests *.

This feature is remarkably well seen on the western slope of the Scarabins, where the white brecciated conglomerate, in twisted sheets, dips off the various shoulders of the quartz mountain, to the W.S.W. and N.W. Other conglomerates, whether capping the detached and lofty Morven, or its peaked and low satellites, the Maiden Pap and the Schmian, being further removed from the pure quartz, are more or less red, and were described by Professor Sedgwick and myself thirty-one years ago, when we ascended the Schmian †.

In descending the River of Langwell, the usual conglomerate is seen to be equally local; for there, whether it rests upon the newer gneiss and grey-coloured flagstones, or on the associated and eruptive granitic rocks which range from the Ord and across Ousedale, it is found to be of a prevailing red colour, chiefly due to the prevailing quantity of granitic fragments. In further descending the stream from these bosses of conglomerate to the bridge under the House of Langwell, a grand succession of thin-bedded deep-red sandstone is exhibited, which, dipping to the E. and E.N.E., cannot have less than a thickness of 800 or 1000 feet.

Now, all this thin-bedded sandstone (fig. 9, *b*, *c*), which passes under and graduates upwards into the series of Caithness flagstones, did not afford to the patient search of Mr. Peach the trace of a fish, any more than it did to my former endeavours. It is this great lower member of conglomerate and thin-bedded sandstone, which I have no hesitation in considering to be the representative in time of the

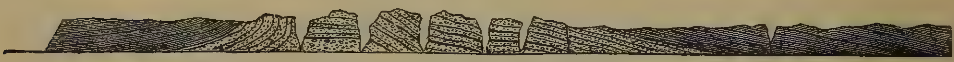
* I made this last examination from the hospitable mansion of the Right Honourable the Speaker and Lady Charlotte Denison, in September 1858. The Scarabin is probably derived from the Gaelic word *Skearach* (rough), and *ben* or *bein* (hill).

† See Trans. Geol. Soc. 2nd ser. vol. iii. p. 138.

*Cephalaspis*-zone of Shropshire and Herefordshire in England, and of Forfar and Perth in Scotland.

I examined the partial uprise of these lower beds through the Caithness flags at Sarclet, four miles south of Wick,—a point to which my attention was called by Mr. Peach. When seen from the sea, as represented in fig. 10, it is manifest that the lower rocks have

Fig. 10.—*Section of the Lower and Middle Members of the Old Red Sandstone at Sarclet, near Wick.*




been protruded by great force, which has subjected the whole of the flanking series of flagstones to extensive transverse breaks and fractures, which, on examining the shore, are found to exist with partial reversals of dip. The little thriving fishing-station of Sarclet is one of those numerous indentations of the coast of Caithness which the stormy eastern ocean has helped to open out, but which, like many of the other coast-clefts which I have seen, is mainly due to an original powerful dislocation, resulting in transverse gullies which the sea has simply widened or deepened. Here the breccia or conglomerate, as at the Ord of Caithness, is made up chiefly of granite and quartz-rock, both grey and white: the imbedded fragments, from the size of a bullet to that of a man's head, are sometimes angular, but often rounded as if they had undergone shore-action. Piled up in massive beds of from 15 to 20 feet each, which alternate with deep-red shaly layers, this conglomerate, where I examined it (for it folds over in a very broken arch), dips to the north, and passes under strong-bedded, hard, fine-grained micaceous grit, freckled with marks of iron-ore, which in its turn is covered with thinner beds distinguished by their rippled surface. This upcast broken mass is seen to be covered by the flagstones, which, as we ascend in the series, whether by going towards Wick on the north or to the Yarrow Hills and to Latheron on the west and south, become fossiliferous and constitute the bituminous flagstone group. It is worthy of remark, that even some of the lower red grits and sandstones effervesce with acids, like many portions of the overlying Caithness flags.

Another spot where the older conglomerate and sandstone have been protruded through the broken undulations of the Caithness flags, is at Dirlet Castle, in the interior of the county, and about twelve miles W.S.W. of Thurso, to which Mr. Peach and myself were directed by that zealous and able explorer of rocks and fossils, as well as of living plants, Mr. Robert Dick (see fig. 11). There a boss of flag-like gneiss (probably the newer gneiss, but largely affected by intrusion and pierced by granite), which is covered by the ruins of the old castle, stands out of the middle of the Thurso Water. This crystalline rock, dipping sharply to the E.S.E., is surmounted, as shown in this diagram, by a coarse conglomerate, almost a breccia, which inclines to the N.E. at about 10°, and soon graduates up into purplish and grey siliceous and micaceous thin-bedded sandstones, covered by the true dark-grey (in parts almost bluish) flagstones, which, after curvatures (doubtless accompanied by breaks which are hidden by moss), become highly fossiliferous in the adjacent hills of Bannis-kirk, &c.

Fig. 11.—*Section showing the Relations of the Lower Members of the Old Red Series near Dirlet Castle.*


* Gneissic and flaggy schists, penetrated by granite. *a.* Granitic conglomerate, or lowest member of the Old Red Series. *b.* Sandstone. *c.* Caithness flagstones.

In following the Old Red conglomerate southwards along the eastern part of Sutherland, where it forms the inland boundary of the coast-range of the Oolitic beds of Helmsdale, Clyne, and Brora, which it separates from the crystalline rocks, the mass may much more truly be called a breccia; for here the included fragments, which are lodged in a paste of pink-coloured or granitic sand, are micaceous fragments of all the varieties of the quartz-rock series, viz. hard, micaceous, finely laminated sandstones of various colours passing on the one hand into gneiss, and on the other into pure quartz-rock.

On the south flanks of Wyvis, the loftiest mountain of Ross-shire, the gneissose flagstones are truncated, and flanked by enormous masses of conglomerate and sandstone, in which are deep rents wherein the streams descend to the Bay of Cromarty. One of the most remarkable of these gorges is watered by the Alt Grant, the massive conglomerate precipices on the sides of which have been described by Sedgwick and myself*; another is that in which the Alness River flows. In ascending that stream above the House of Ardross, the formation is perceived to assume an aspect differing a good deal from its usual appearance. In their upper parts the beds are of dark-grey, greenish, and deep-red soft shale, either highly inclined or in rapid undulations, and in the lower part of a very coarse conglomerate and a reddish and yellowish, gritty, thin-bedded sandstone. The lower portion of the conglomerate is here not only vertical and much twisted, but is also much mineralized and contains a thick vein of rich hematitic iron-ore. All these lower beds of the Old Red have been deposited quite athwart the edges of the quartzose flagstones and mica-schist of Wyvis and its adjacent mountains, which have the usual dominant strike of N.N.E. or N.E. and S.W., whilst the conglomerate and sandstone of this tract strike nearly east and west, and dip southerly at angles decreasing as you recede from the mountains.

Allusion was formerly made to the bold forms which the Old Red

* Trans. Geol. Soc. Lond. 2nd ser. vol. iii. p. 147.

conglomerate assumes in various hills where it rises in more or less rounded pyramidal masses, which have been embossed as it were on the edges of the crystalline rocks. Good examples of this are given in the fly-flap of the coloured section given by Sedgwick and myself, where the Maiden Pap and Morven rise above the adjacent quartz-rocks, and again where the hill of Meal Turach stands out in Ross-shire above the gneissose rocks of Loch Glas, at the foot of Wyvis*. The hill of Ben-a-vraggie, above Dunrobin in Sutherlandshire, on which the monument of the late Duke of Sutherland stands, is also a striking example of these lower conglomerates.

At Skibo Castle, the seat of my friend Mr. Dempster, a deep-red coloured sandstone has been opened out in the lower division of the formation, the strata of which dip away from the slopes of gneissose hills to the Dornoch Firth; and in this sandstone Miss Dempster procured two incurvated casts about 8 or 9 inches long, which, terminating in points, rudely resemble the pincers of a huge Crustacean. If these casts should prove to be referable to some such creature as the *Pterygotus* of Herefordshire, Shropshire, Forfarshire, &c., they stand as yet alone as indications of animal life in the Lower Old Red of the North-east of Scotland.

In this vicinity and in the much higher beds which shelve away on the coast near Embo with an easterly dip, the sandstones become more yellow, and range along the shore to the town of Dornoch. Near Embo they contain strong pebbly beds, and are marked by blotches of deep-red shale, occasionally circular. In these same beds and among the pebbles which have been chiefly derived from the crystalline rocks of the interior, Mr. Peach and myself detected some fragments of those cherty and very peculiar beds of the Durness and Assynt limestone, as well as portions of quartz-rock. In following these upper ledges from Embo to Dornoch, the rock is well exposed in quarries which have been opened for the construction of the new buildings in the town; and the yellow and even whitish-coloured sandstone there predominates over the deep-red, the latter being thrown away as refuse. Now, as these light-yellow strata with occasional pebbly beds are inclined gently to the S.S.E., they (as well as the sandstones of Tain and Tarbet Ness) seem to form the north-western side of a wide basin, the south-eastern side of which reappears on the opposite side of the Moray Firth, near Elgin, where similar yellow sandstones occur.

In Ross-shire, the quartzose micaceous schists and gneiss through which the Rivers Connan and Orron flow from the central highlands and the mountains of Strath Connan and Strath-glas, have the prevalent dip to the E.S.E., and are admirably exposed on the banks of both those rivers, just where they issue to the low tract of Easter Ross. At no spot is the unconformity between these crystalline rocks and the Old Red Sandstone better seen than to the west of the ancient Tower of Fairburn†, where a feeder of the Orron flows over

* Trans. Geol. Soc. Lond. 2nd ser. vol. iii. pl. 14. figs. 3 & 5.

† The seat of the Mackenzies of Fairburn, my maternal ancestors, who possessed the estates of Fairburn, Strath Connan, and Monar.

mica-schist inclined to the E.S.E. at 70°, the edges of which are covered by a coarse red conglomerate, which in descending to the low country in the same direction, but at much lower angles, is beautifully displayed on the banks of the Orron,—the river cascading over beds of pebbly conglomerate and intercalated hard sandstone, and the whole subsiding under the red sandstone of the Black Isle. In like manner when we pass to the south side of the Beauley River we find the crystalline rocks of Strath-glas similarly flanked by the Old Red conglomerate and sandstone, which, ranging from W.S.W. to E.N.E. along the south side of the Murray Frith, repose on the crystalline rocks and dip to the N.N.W.

We thus learn that the Old Red conglomerate and sandstone are everywhere thrown off from the broken and protruding edges of the older rocks, and that the direction and indication of these regenerated deposits vary with each great promontory.

But besides these main base-lines, there are other and minor ridges of elevation, by which, whether by the rise of granite or granitic gneiss, the conglomerate and bottom rock of the Old Red are exhibited. Such, for example, is the uprise of the granitic and felspathic rocks, with metamorphosed strata, in parts a true gneiss, at the mouth of Cromarty Bay. There, however, the conglomerate is feebly exhibited only; but by following the same line of elevation along the East Coast, other gneissose and granitic rocks (evidently metamorphic and eruptive) protrude into the altered rocks, extend to Fortrose and Avoch, whence to Kessock Ferry House, opposite Inverness, there is a most instructive development of the conglomerate and sandstone. Of this sandstone there are fine quarries at Avoch, the beds being in highly inclined positions, dipping away from the eruptive rocks of Craig Wood.

Nowhere in Ross-shire is the conglomerate better displayed than on the coast extending from the south of the Bay of Munlochy by Kilmuir to Drynie, and in the cliffs between that place and Kessock Ferry opposite Inverness. Whether in the headland called Craigie How, in which a large natural cave is opened out upon the inclined plane of the beds, or in adjacent spots where freestone is intercalated, the strata are seen to dip inland, or from 50° to 70° and 80° to the W. and W.N.W. Hence we see how, along this coast-line of elevation, the red sandstone of Redcastle, Taradale, and other places in the Black Isle where the red sandstone is quarried, is in alternation with conglomerates which here and there rest upon crystalline rocks.

The traveller who reaches Inverness from the South, and has a short time only at his disposal, will indeed do well to cross the Kessock Ferry, where, keeping to the sea-shore and passing by Craigton to Drynie, he may examine many remarkable masses of the conglomerate with irregular courses of hard, finely laminated, quartzose sandstone, so made up of granitic detritus that they often look like granite-veins traversing the conglomerate. The latter is there compounded out of various granites (including those which abound on the shores of Loch Ness), of red porphyry, and of much quartz-rock, whether grey, white, or brown; whilst fragments of mica-schist and gneiss are the smallest and least abundant materials. The largest boulders in this coarse conglomerate are about four feet in length, and, differing from those of the breccia of the east of Sutherland, they are all rounded. The dip of all these beds is also 70° to the W.N.W., or sharply inland, thus seeming to throw the Old Red Sandstone of the Black Isle into a trough.

Succeeding to these coarser conglomerates, but alternating with pebble-beds, are the chief freestones of the group, which are so extensively used for building-purposes throughout the counties of Ross, Cromarty, Inverness, Nairn, Moray, &c. This sandstone, of which quarries are opened in numberless localities, is of very varied tints of red, is occasionally much variegated either by greenish and whitish spots of earthier matter (Thon-Gallen of the Germans), or by a regularly ribboned or striped structure of thin layers of deep red alternating into lighter and yellowish laminæ of deposit. In short, we find in the rock those lithological features, which in the early days of geology were erroneously supposed to be characteristic of the New Red Sandstone only, but which are now known to be prevalent not only in the Old Red, but also in the red and variegated Lower Silurian or Caradoc freestones of Shropshire. In the lower conglomerate and sandstone, as well as in the overlying gritty and pebbly beds with fine building-stones, organic remains have as yet been very sparingly found—a scale or two of a fossil fish being all that I have heard of; and whether it be on the coast of Cromarty, or at Strathpeffer in the interior of Ross-shire, it is only when we reach certain schistose beds, often more or less bituminous (the equivalents of the Caithness Flags), that fossil fishes begin to be distinctly recognized.

No identifiable organic remains have as yet been detected in the lower sandstones and conglomerates of this series in the North of Scotland; yet these thick and finely levigated masses are considered by me to represent in time the lowest beds of the Old Red of Forfarshire, Shropshire, and Herefordshire, which contain *Pterygotus*, *Cephalaspis* and *Parka decipiens*—remains which are quite distinct from those of the bituminous schists and flagstones of Caithness.

*Caithness Flags*, or *Middle Division of the Old Red Sandstone of the N.E. of Scotland and the Orkney Islands* (*d* of the section, fig. 9, p. 394).—Having indicated in the General Section, fig. 9, and in figs. 10 and 11, that the Lower Old Red Sandstone and Conglomerate pass up gradually into the Caithness Flags, it is manifest that the latter can no longer be ranked, as they have been, with the lower member of the group,—the more so as I have shown that the ichthyolites they contain are in other parts of the world associated with shells which characterize the middle and upper divisions of the Devonian rocks*. In no part of the British Isles are these flagstones so copiously elaborated, and so rich in fossil fishes, as in Caithness and the Orkney Islands. It is unnecessary that I should here present to the reader accounts of the numerous variations in litholo-

* Russia in Europe, vol. i. p. 64; Siluria, new edit. p. 382; and *infra*, p. 414.

gical composition which these rocks assume in different parts of their range, or attempt to describe their numerous undulations as well as the powerful fractures to which they have been subjected. Lithologically described many years ago by Sedgwick and myself, and since then treated of in my own publications*, they have acquired a wide celebrity for their great economical value, whilst they are deeply interesting to the palæontologist as containing those numerous ichthyolites described by Hugh Miller and Agassiz.

The real study of these flagstones is best made upon the coast-cliffs, from the lowest strata near Dunbeath to their central parts at Wick, and thence to the highest beds on the shores of the Pentland Firth, where they pass up into the overlying sandstones of Dunnet Head (fig. 9, p. 394). Many of the beds are so bituminous, owing to the quantity of animal matter they contain, that even in 1827 they were described by me as bituminous schists†.

One of the most instructive ascending sections in the environs of Thurso is made (as pointed out to me by Mr. Robert Dick) by proceeding from the gneissose rocks of the Dorrery Hills on the W.S.W. to Thurso and Holborn Head on the E.N.E. In this district the observer proceeds from the crystalline rocks through a vast thickness of superposed strata. The lowest of these, as usual, are breccias and conglomerate, followed by various sandstones in parts calcareous; and then follows the flagstone series, in which Mr. Dick enumerates from 13 to 15 varieties, including sandstones, one variety of which, at the old Bishop's Castle near Thurso, is used as a building-stone. This flagstone series is extended into the various headlands of the north coast, and is prolonged eastwards in broken undulations to Dunnet Head, Duncansby Head, &c. Until a correct map of the county be constructed, it is difficult, if not impossible, so to lay down the range of the strata as to show those parts where the flagstones expand to vast dimensions, and where they are affected by powerful and numerous fractures and faults‡; for, though the outline of the country is on the whole one of gently sloping hills and plains, the fractures to which the strata have been subjected are powerful and numerous. Many of these dislocations are well exhibited in the coast-cliffs; and according to Mr. Robert Dick they are equally abundant inland, and particularly around Loch Watten. Hence it is very difficult to form an estimate of the thickness of the flagstone group. There are, however, tracts (as between Lochs Rangan and Stemster, and again between the Dorrery Hills and Banniskirk) where

* See particularly the last edition of 'Siluria,' in which the Chapter on the "Old Red Sandstone" was printed long before these memoirs were read.

† Trans. Geol. Soc. Lond. 2nd ser. vol. ii. p. 314.

‡ Spreading out a heap of flour upon the board of his bakery, Mr. Robert Dick, who had heard me complaining of the want of any map of Caithness, produced, in a short time, a model, in relief, of the ground and drainage of this county, the geography of which (with the exception of the excellent charts of the coast made by the Admiralty Surveyors) is in a worse state than in any part of Scotland. I blessed the Duke of Sutherland for having had a good map of Sutherland executed, whilst the want of any map of Caithness approaching to accuracy is sorely felt by the exploring geologist.

the persistent inclination of superposed strata (in the last case to the E.N.E.) induces Mr. Dick as well as myself to assign very considerable dimensions to the deposit.

The manager of Mr. Traill's large quarries at Castle Hill (Mr. McBeath) defines sixteen different beds, nearly all of which, to the ordinary eye, present a great sameness of structure. Seeing the indestructible character of this hard pavement-stone, which resists the weather, even when set on edge to form fences, I suggested, when on the spot, that their great tenacity and resistance to the atmosphere were in all probability due to the fine admixture of silica and alumina, in a finely pulverized condition, with certain proportions of carbonate of lime and bitumen (the latter chiefly obtained from the numerous fossil fishes of the deposit), with traces of iron. The analysis of Dr. Hofmann, to whom I submitted four varieties of the flagstone of Castle Hill, taken from the base, middle, and summit of the Castle Hill quarries, has confirmed the view as given in the Table of the accompanying footnote*. Where the

* Table.

| Mineral analysed. | Silica and Silicates, insoluble in HCl. | Oxide of Iron and Alumina. | Carbonate of Lime. | Organic matter. | Water, loss at 100°C. | Salts of Magnesia, the Alkalies, &c. | Total. |
|---|---|---|---|---|---|---|---|
| No. 16. Top flag. . | 68·40 | 10·21 | 10·93 | 3.88 | 0·42 | 6·16 | 100·00 |
| No. 7. Middle flag | 69·45 | 11·50 | 10·66 | 5·79 | 0·40 | 2·20 | 100·00 |
| Bituminous Shale. | 69·96 | 8·15 | 7·72 | 10·73 | 0·53 | 2·91 | 100·00 |
| No. 1. Bottom flag | 61·39 | 4·87 | 21·91 | 3·40 | 0·20 | 8·23 | 100·00 |

In analysing a portion of the bituminous schists from the property of the Earl of Caithness (near Barrogill Castle), Dr. Hofmann reported to me as follows:—"When submitted to the action of heat, this substance evolves a considerable amount of gas, and likewise of oily matter containing a certain proportion of ammonia. The residue which remains behind is a greyish mass, consisting essentially of silicate of alumina (clay) mixed with a certain quantity of sesquioxide of iron and of sulphate of lime. A very minute proportion of phosphoric acid was likewise found to be present. The loss which the mineral undergoes on heating was found in two consecutive experiments to be 30·21 and 30·02; so that the mineral may be said to contain, in round numbers,

"Fixed matter (mineral) 70 per cent.; volatile matter (organic) 30 per cent.

"In determining the amount of gas furnished by the distillation of the mineral, a portion of it was heated in an iron tube, in order to imitate, as nearly as possible, the circumstances of an operation on a large scale. In two consecutive experiments which were performed in this manner, 100 grammes furnished in one case 7690 cub. centim., and in another 7430 cub. centim.

"Assuming then 100 grammes of the mineral to yield, on an average, 7500 cubic centimetres of gas, a ton of the material would furnish 2690 cubic feet. The ordinary varieties of coal used in gas-making yield from 8000 to 10,000 cubic feet of gas per ton. The gas obtained from the mineral is very luminous; it is nearly entirely free from sulphur, and it is on this account very readily purified. The residue left in the retort after the expulsion of the gas retains but a small amount of carbon, viz. 8·5 per cent.; this residue has therefore but little value as coke.

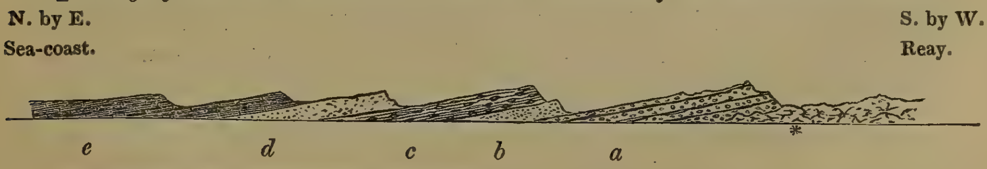
"The mineral in question is in no way related to ozokerite, as has been suggested. From that substance it may be at once distinguished by its infusibility (ozokerite fuses at 80° C.=176° Fahr.), and by its entire insolubility in alcohol and ether, in which solvents ozokerite, although with difficulty, dissolves."

quantity of bitumen increases to so great a degree as to exude from cracks and fissures in the stone, the quality of the paving- or floor-stone necessarily diminishes; but when the value of this bitumen is sufficiently known, the flagstones permeated by it may be largely quarried for lighting and other purposes.

Revisiting that portion of the north coast of Sutherland which confines upon Caithness, and which was formerly described by Professor Sedgwick and myself, I found that, whilst the lower part of the Old Red series in the tract extending from Strathy to Reay exhibits in many places (and particularly near Port Skerry) shore-ledges well exposed at low water, of powerful coarse breccia made up of granite, porphyry, and the flaggy gneiss which is penetrated by these rocks, this coarse breccia, including huge angular blocks from 2 to 3 feet in size, is, notwithstanding many breaks, observed to be surmounted by sandstone of lightish colour, which, though it weathers to a brownish red colour, cuts, as a freestone, to a whitish tint. The thick-bedded sandstone with pink grains is surmounted at Balligill by dark-grey ichthyolite-flags charged with *Coccosteus*, *Osteolepis*, *Dipterus*, *Diplopterus*, *Cheiracanthus*, and certain plants. These beds graduate into limestones which have been extensively worked for use, one of the beds being 3 feet thick and followed by thin flaggy courses. On the whole, however, the lower part of the series in its western extension is already seen to be parting with the character which is dominant in Caithness, and is becoming more a sandstone formation, with included limestone.

The bosses of the granite on the shore near Port Skerry have evidently penetrated, when in a molten state, into the gneiss, whilst both these rocks have afforded the fragments composing the lower breccia and conglomerate. In truth, all this part of the coast having been subjected to violent breaks and faults, the hard crystalline granite, porphyry, altered rocks, and gneiss have in such movements been necessarily protruded here and there through the softer sandtone and flagstone. But that all such crystalline rocks were previously solidified, is proved by the fact that their materials forming the breccia and conglomerate here constitute the highly irregular base of the Old Red series. This angular breccia, evidently formed under tumultuous conditions, alternates, however, with fine-grained, hard, siliceous sandstones, into which it passes up, and finally into building-stone.

Fig. 12.—*Section along the Burn of Isauld, near Reay, showing a passage from the Lower to the Middle Member of the Old Red Series.*




* Granite. *a*. Granitic red conglomerate. *b*. Hard grey siliceous sandstone. *c*. Calcareous dark-coloured flagstone, with geodes of limestone. *d*. Soft light-coloured sandstone. *e*. Ordinary dark-grey Caithness flags, with ichthyolites.

In proof of the very local character of the coarse breccia, the observer has only to move a few miles eastward to Reay, and, in descending the banks of the little Burn of Isauld to the sea-shore, he will find that there the fundamental granite has undergone no dislocation, and that the conglomerate, or base of the Old Red lying on it, consists of pebbles which have evidently been rounded by the long-continued action of waves upon a shore, while the lower part of the flagstones, presenting the same predominance of sandstone as above remarked, and containing some limestone, passes in even and unbroken beds under the great mass of the Caithness series with its fossil fishes. The order is represented in the section, fig. 12.

*Fossil Remains in the Caithness Flags.*—I have little new matter to add in respect of the animal remains of this deposit of flagstones. The genera and species of the fishes are already well known; but I may state that a specimen of a *Coccosteus* lately discovered by Mr. Peach exhibits a vertebral column more completely ossified than that of any hitherto-discovered specimen. Again, it is to be noted, that the *Asterolepis*, found by Hugh Miller in the lowest beds of the Orkney succession, has been detected, both by Mr. John Miller and Mr. Peach, in the highest beds of Caithness. Of the prevalent genera, *Osteolepis*, *Dipterus*, *Cheiracanthus*, *Diplopterus* and *Coccosteus*, the fish usually lowest in the strata of Caithness is the *Osteolepis*; it may also be stated that a *Pterichthys* has lately been found in the Orkney Islands.

I must not omit to speak of the only shell, or rather shell-like Crustacean, yet discovered in these flags, and which occurs abundantly at Kirkwall in the Orkneys, and has also been found near Lerwick in the Shetland Isles. This is a small *Estheria*, a Phyllopodous bivalved Crustacean, such as are found in African and South American rivers. It is about half-an-inch long, and marked by sharp concentric lines of growth, and has the general aspect of a small *Astarte*, or *Venus*. It occurs in certain localities in such numbers as to form layers an inch or two thick, entirely made up of the thin carapaces. It has been described for me by Mr. T. Rupert Jones, and is named by him *Estheria Murchisoniana*.

### *Description of a small Bivalve Crustacean from Caithness.*

Estheria Murchisoniana, spec. nov. Woodcut, fig. 14, *c*, *d* (p. 408).

The carapace-valves of a small bivalve crustacean, occurring plentifully on some of the surface-planes of the Caithness Flagstones, near Wick, and also in the Orkney and Shetland Isles, have been noticed by Hugh Miller and others *. Their close resemblance to the shells of small bivalve molluscs formerly led to their being taken for the shells of *Venus*, *Cyclas*, &c.; but their supposed relation to molluscs having been doubted, some specimens from near Thurso, collected by Mr. Peach, were given to me by Mr. Woodward; and a far larger number, and better preserved, from Kirkwall and Murkle Bay, were confided to me for examination by Sir R. Murchison last winter.

In their substance, consistence, configuration, and size, these little valves offer

* See Dr. Malcolmson's Memoir, *antea*, p. 351; Miller's 'Old Red Sandstone,' 4th edit. p. 132, pl. 5. fig. 7; and Sir Roderick Murchison's remarks above; and at pp. 411, 413.

direct analogies to the bivalved carapaces of certain recent Phyllopodous Crustaceans inhabiting the rivers and lagoons* of hot countries, and often much resembling the shells of *Nucula*, *Cyrena*, &c.

Great numbers of the valves are spread over large surfaces of the flagstone, sometimes scattered sparsely, sometimes congregated in groups, forming films between the layers of the fissile stone. Sir Roderick remarks (above, p. 404) that their distribution appears to be very local;—I have not learnt how thick the band, or bands, of the flagstone may be that they affect. The valves are usually single; pairs, with their hinge-lines in juxtaposition, are rare. The specimens which I have are in dark-grey, tough, fine-grained, sandy flagstone, slightly micaceous, somewhat varying in tint and hardness. They usually appear to have a superficial smoothness or even gloss, and often a light-brown tint, with some degree of translucency. But the substance of the valve flakes off readily, leaving a film on each of the two surface-planes in a split stone; and it is comparatively seldom that a valve shows its real exterior; for, though the surface may sometimes come away from the stone in splitting, and leave a clean cast, yet an outer flake of the valve seems nearly always to have fallen away with the shock of the blow; and the sandy nature of the matrix is too coarse to retain traces of any very fine microscopic sculpturing in the cast or mould of the surface.

In the Kirkwall specimen the valves are pyritized; but those from Caithness retain their brown horny tissue, although the outermost surface is seldom preserved, and only in little patches on some valves. From this circumstance it is very difficult to form a correct diagnosis of the species; for the superficial ornamentation yields important specific characters in this genus, and in this case it cannot be well studied.

A careful examination of the materials at my command enables me to describe the carapace as follows:—

Valves variable in shape from a subquadrate to an oblong form,—some being about $\frac{1}{6}$th inch long and $\frac{1}{8}$th inch high, and others being as high as long. The hinge-line is straight; the generality of the valves have the anterior and posterior edges forming sharp angles with the dorsal line and passing vertically with a slightly convex outline to the boldly-rounded ventral border. In this case the umbo is distinct, almost in the middle of the back line, and bordered by a triangular depressed ear on either side; something like a miniature *Cucullæa auriculifera*.

There are also valves which are longer and narrower, with the ends rather more convex, and the ventral border somewhat straight. Here the umbo is less protuberant and nearer to one end (the anterior?).

In each of these forms the surface is wrinkled, by about 18 to 20 concentric, rounded, closely-set ridges, uniform with the outline of the ventral border and extremities of the valve. The ridges are coarsest near the umbo, their starting point, and they become finer as they approach the edges of the valve.

Under the microscope, the patches of the outer surface, here and there retained, are seen to be of a dark-brown opake substance, exhibiting on and between the ridges a finely granular appearance, which is probably the real condition of the surface; or it may be due to an accidental modification of an originally minute reticulate ornament.

As it is possible that the difference in shape between the many subquadrate and the few oblong valves may be due to pressure, to a condition of growth, or perhaps to difference of sex, it would be too hazardous even to distinguish them by name as varietal forms †. Indeed, circumstances have so modified the great majority of the valves, that the whole outline of a valve can very rarely be definitely traced even among a hundred individuals; for the edges either

* The *Estheria minuta* of the Trias is the subject of a note in the Quart. Journ. Geol. Soc. vol. xii. p. 376; and I have there referred to the Caithness form. The information, accompanying a recent specimen, which led me to term *Estheria* a "marine" crustacean (*op. cit.* p. 377), is, I find, probably erroneous, or at least requires to be substantiated.

† In one or two instances I was almost misled by apparently elongate valves, which were, in truth, two valves pressed accidentally one on another "conformably," but still one extending a little beyond the other.

overlap, or are squeezed out of proportion, or are broken away, or, lastly, remain buried a little way in the matrix.

I had hoped to have completed an account of all the known fossil Estheria-like Crustaceans before offering any remarks on these Caithness specimens. But, for the present, I can only observe, that the form most like to them that I know of is the so-called *Posidonomya Keuperiana* of Germany (as far as some few casts which I possess can show). Still there is a slight difference as to shape (I have as yet no means of comparing the valve itself of the German triassic form referred to), and I prefer to regard them as distinct; and I cannot do better than dedicate this fossil *Estheria* of Scotland to one who has devoted so much labour and time to the elucidation of its geological relations.

Mr. Salter has lately shown me some specimens from Russia which appear to be identical with *Estheria Murchisoniana* (but in a matrix of light-grey clay very different from the Caithness flagstone). These are labelled "*Asmusia membranacea*, R. Pacht;" but I do not know whether they have been described. It does not appear to me at present that there are any grounds for separating these fossils from the recent genus *Estheria*. The term *membranacea*, having been already given to one of the Wealden *Estheriæ* (*Cyclas membranacea*, Sow.), is preoccupied.—July, 1859. T. R. J.

The following passages respecting the fossil plants of this deposit are extracted from the last edition of 'Siluria':—

*Plants of the Caithness Flags.*—The most marked addition to the fossil contents of the Old Red Sandstone consists of various fossil plants. Even as late as the year 1854 I could allude to only one unquestionable land-plant as having been found in this formation by Hugh Miller, and described by him as a part of a Coniferous tree. The same author had afterwards brought to the notice of the British Association for the Advancement of Science, in 1855, several of these fossil plants, which have since been published in his posthumous work the 'Testimony of the Rocks.' Most of these have been there referred to tree-ferns and illustrated in that work by woodcuts.

Living at Wick, in the central portion of the Caithness flags, Mr. C. Peach has laboured incessantly in that locality to discover organic remains, and has succeeded in disentangling certain fossil vegetables (as well as many ichthyolites) from these hard rocks. The plants are all clearly of terrestrial origin, and are of the same species as those which have been found in the Orkneys by Dr. Hamilton, and at Thurso by Mr. John Miller and Mr. Robert Dick, who have collected many excellent specimens near that town, some of which are figured below.

[These fossil remains of vegetables have been figured and described at large in the Quart. Journ. Geol. Soc. (vol. xiv. p. 72, pl. 5) by Mr. Salter, who has also supplied the following succinct notes on the plants.]

The most striking, perhaps, of these fossil plants are very large, long, flattened bodies, which, from their state of preservation, were clearly woody stems (fig. 13. 6). They were 4 or 5 inches broad, and as many feet in length, fluted longitudinally, and possessing a central pith. Though these plants have often been converted into thin plates of crystalline coaly matter, their forms remain distinct, and, under the careful microscopic scrutiny of Professor Quekett, they have exhibited a true coniferous structure. In the arrangement and number of the disks upon the fibres, they approach near to the Araucarian group. In general appearance, and even in the mode of preservation, they strikingly resemble certain fossil forms from the Upper Devonian rocks of Saalfeld in Germany, collected by Dr. Richter,—such, for instance, as the *Aporoxylon* of Professor Unger; but this differs in being of simple structure, and possessing no pores or disks on the woody fibre.

These fluted fragments are without doubt stems; and similar but more slender specimens found with them are as clearly the branches, which have borne whorls of smaller twigs, like their living representatives. Again, large branching woody roots, fig. 13. 5, but destitute of superficial markings, appear to have belonged to the same trees, and are often several feet long. With these occur very many specimens of a *Lepidodendron*, 4, with short scaly leaves—*L. nothum*, Unger?

or a species very like it; a *Lycopodites*, 3, with long prostrate stems and secund or one-sided foliage, like that of the common *Lycopodium clavatum*. This last may of course be of quite a different natural order, and even coniferous; but its general resemblance alone is implied in the name.

Linear branched or dichotomous fragments, some of them smooth (1, 2) and destitute of all markings, have also been found, whilst others, like them, are covered with small tubercles in quincunx order, and are probably the roots of the *Lepidodendron*, 4.

The probability of the smooth forms, 1, being also roots, is very strong. Similar bodies occur in beds of the Upper Devonian series in N. Devon and the South of Ireland, and in such a position with regard to the fluted stems of *Knorria*, with which they are associated, as to lead to the belief that they are the rootlets of that plant. The larger ones have even markings similar to those of the main stem.

This probability is strengthened by finding similar linear specimens with them, which bear tubercles or excrescences at their tips and along their sides very like those on the roots of Leguminous plants and many of the Conifers. The latter is the more probable analogy.

Hugh Miller has, indeed, figured a similar fossil as probably belonging to an ancient marine plant resembling the *Zostera*, and has reasonably speculated on the existence of wide fields of such vegetation on the muddy shores of the Old Red period. But our more perfect specimens justify the belief above-stated; and as yet there is no evidence of any marine plant in the Caithness schists. The vegetable remains have evidently been swept from adjacent lands into the sea inhabited by the fishes above-mentioned.

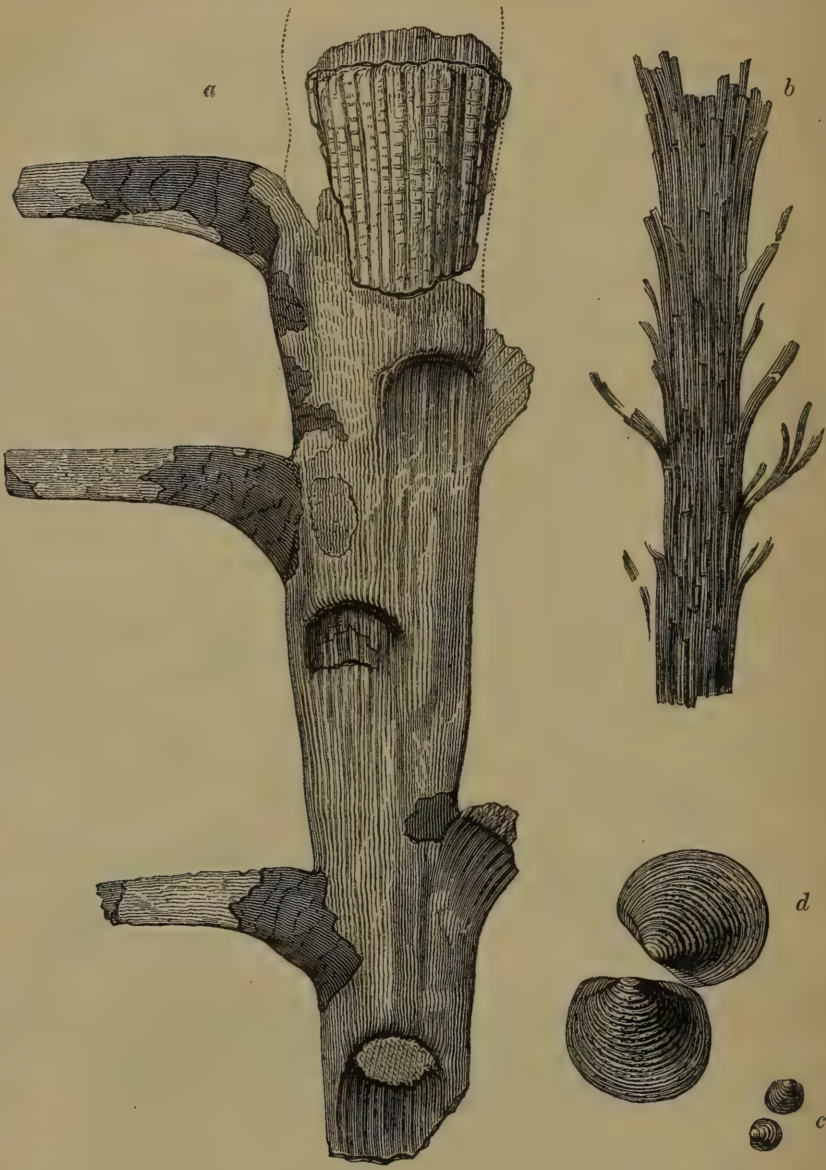
Fig. 13.—*Fossil Plant-remains from the Old Red Sandstone of Caithness.*

(From 'Siluria,' new edit. p. 290.)


1. Branched rootlets of some Lycopodiaceous ? plant. 2. Dichotomous roots (very common) of *Lepidodendron* ?, upon a surface marked with double annelide-burrows. 3. *Lycopodites Milleri*, Salter; one-third nat. size. 4. *Lepidodendron nothum*, Unger ?, one-third nat. size. 5. Flattened root, and 6. Fluted stem, of Coniferous tree, about one-sixth nat. size.

A fossil plant very recently found differs from any one hitherto published, and is so peculiar, from the rectangular setting-on of its lateral branches, that it is here figured; and, though its genus is doubtful, it has at my request been named (after its discoverer) *Caulopteris? Peachii*. See fig. 14. The stem is wider beneath each branch, and striated for a short distance.

Fig. 14.—*Fossil Plants and Crustacean from the Old Red Sandstone.*




*a*. Stem of Tree-fern (*Caulopteris? Peachii*, Salter); ⅓rd nat. size. Thurso.
*b*. Young shoot of a Coniferous? plant, showing leaves; half nat. size. Duncansby Head.
*c*, *d*. *Estheria Murchisoniana*, Jones; nat. size and magnified. Murkle Bay, Caithness (collected by Mr. R. Dick).

The flora, then, so far as can be made out, consisted of Coniferous trees, some of considerable size*, and, according to their minute structure, of the Araucarian type; *Lepidodendron* also is rather abundant, and a *Lycopodites* occurs. It is but a scanty assemblage, after all, as to species, but may be compared with that flora recently detected by Prof. Dawson in the Devonian beds of Nova Scotia, where *Coniferæ* of a somewhat different type, and *Lepidodendra*, are the chief forms described †. On the whole, it is analogous to that of the Carboniferous formation, though distinct as to species. There were large Coniferous trees—with whorls of branches, and with a structure like that of the Norfolk-pine; also *Lepidodendron*, *Lycopodites*, and Ferns. That these grew near the coast and were entombed in the shallows of a muddy shore, seems proved by their good preservation and from the coarse nature of the matrix, which is, moreover, indented by the burrows of sea-worms, like those made upon the shores in our own day.

As we advance still higher in the series, or into the strata which overlie the Caithness flags, other fossil plants of large size begin to appear; and several of these have been discovered in the Orkneys and Shetlands by Mr. Tufnell and Dr. Hamilton, and belonging either to *Columnaria* or to some allied genus, make an approach to forms usually considered as characteristic of the Carboniferous era (p. 413).

*Upper Old Red of Caithness.*—In various parts of the north coast of Caithness the series of dark-coloured flagstones, nearly all more or less bituminous, is seen to graduate upwards into light-coloured sandstone, in parts reddish, but usually of yellowish colours. At Reay, indeed, such sandstones are developed so very low in the series (see Section, fig. 12, p. 404) as to be interlaced with some of the lowest beds of flagstone. Here and there, as between the town of Thurso and Holborn Head, a band of this character is intercalated higher up among the flagstones, and the beds, being thicker and softer than the associated flagstones, are used for building.

Fig. 15.—*Section showing the relations of the Caithness Flags to the Upper Old Red Sandstone in the neighbourhood of Dunnet Head.*


In the bold promontory, however, of Dunnet Head, the observer ascends from the flagstones as exhibited on the coast from Barrogill Castle to the fishing-villages of Ham and Brough, as represented in the Section, fig. 15, where, after several undulations and breaks, those dark bituminous and ichthyolitic beds are carried under the

* A large carbonized stem similar to those first mentioned (p. 406) has recently been discovered by Mr. Peach. It measured several feet in length by sixteen inches in breadth, thus proving that these Old Red plants attained the dimensions of large fir-trees.

† Proceed. Geol. Soc. January 5, 1859.

headland of a yellowish sandstone, occasionally weathering red. When viewed from Castle Hill, *i. e.* on its western side, this headland presents a reddish exterior; and it is partially so externally on the north and eastern faces; but when closely examined on the last-mentioned flank, the rock, which rises in terrace over terrace to the Lighthouse, 340 feet above the sea, is on the whole of a yellowish colour. The lowest beds visible near Brough are of reddish-brown colour, with blotches of light-coloured, and occasionally greenish, crystalline spots; the next ledge is a thick-bedded, finely-laminated, slightly micaceous freestone, weathering white, but partially of yellowish-brown tints. The higher courses consist of strong bands of sandstone and coarse grit of whitish, yellowish, and dull brown-red colours, with rarely occurring small pebbles of quartz,—some of the beds, particularly those on the summit of the headland, containing elongated argillaceous blotches or concretions of dark-red and greenish colours*.

These overlying sandstones are much more largely developed in the Orkney Islands than in the county of Caithness.

*Old Red of the Orkney Islands.*—These islands, as far as I have seen them, exhibit essentially the same geological character as the rocks of Caithness. Possessing as extensive a development of the ichthyolitic flagstones as Caithness itself, they exhibit a still greater thickness of the superior and light-coloured sandstone, or third division of the Old Red, than is anywhere to be seen in the main land of Scotland.

In the principal island of Pomona, we observed, at two localities, that the flagstones were underlaid by conglomerate and sandstone. Remarking that the beautiful Cathedral of Kirkwall was built of a red freestone which has retained the sharpness of its architectural ornaments for centuries, and, seeing that the Caithness flags, on which the town stands, dipped away slightly to the north, we passed over eastwards to the Bay of Meal, to look out for a red sandstone of which we had heard, and there found red and mottled sandstone arching over and rising out from beneath the flagstones. As we also detected the same mottled red sandstone on the S.E. side of Scapa Bay, where it is inclined at an angle of 65° to pass under the flagstone series, and trends to the westward, we had no doubt that this rock, which crosses the promontory to the Bay of Meal, was the same which had been worked for the construction of the cathedral. This feature seems to have escaped the notice of former explorers; and the fact proves that the ichthyolite-flagstones have the same base, not only of conglomerate, but also of red sandstone, in Orkney as in Caithness.

The chief masses of rock which succeed, are largely cut into in

* Though we sought in vain for any organic remains in these yellowish sandstones, Mr. Peach has since detected plants in sandstones at Duncansby Head, and also at Friswick, on the east coast. At the former place a conglomerate charged with pebbles of greenstone occurs; and in one of the thin beds of sandstone, a stem, apparently with leaves, was found, which is represented in fig. 14 (*b*).

the east hill above Kirkwall, and may be best paralleled with some of the rocks near Wick,—being hard, tough, and thick-bedded enough to be used as rude building-stones. They are also bituminous, and are here and there copiously charged with fish-remains; for in them we found *Coccosteus* and many remains of other ichthyolites.

These stony bands are followed, on the north side of the harbour, by thin flagstones, which, in addition to numerous ichthyolites, are laden with the little Crustacean *Estheria* (p. 404), which, wherever it occurs, is equally characteristic as the fishes, being abundant in some spots of Caithness, particularly near Thurso. With the exception of the partial axis of the lower sandstone of Kirkwall, and a lower conglomerate near Stromness, which is formed out of and rests upon granite, just like the examples on the coast-confines of Caithness and Sutherland, the whole of Pomona seems to be so occupied by the ichthyolitic flagstones, that if the Roman leader who named the island had been a naturalist, he might aptly have named it *Piscina*. Occupying all the interior hills as well as the plains on which the famous Stennis Stones stand, these flagstones are admirably exposed on the shore to the N.E. of Stromness, where dipping away from low bosses of granite and the conglomerate formed out of that rock, they form broad undulations, all along the northern shore, the cliffs between Breakness and Holbrow rising here and there to 150 feet or more above the sea.

It is unnecessary here to recapitulate the numerous ichthyolites which Pomona has yielded. We ourselves met with *Osteolepis*, *Coccosteus*, *Asterolepis*, *Dipterus*, *Diplopterus*, *Diplacanthus*, and many fossil plants. The works of Agassiz and Miller teem with data on this head,—Dr. Traill having supplied the former with many of the new specimens*.

In availing myself of the opportunity to visit the northernmost of the Orkney Islands (Ronaldsha) and the Shetland Isles, in the steamer of the Commissioners of the Northern Lighthouses, I was prevented from extending the observations made in the environs of Kirkwall and Stromness, into the adjacent island of Hoy. Of the general order, however, in that island, there can be no doubt; for, whether it be viewed from Dunnet Head, from the sea, or when sailing under its cliffs on the east, west, and north sides, or by walking along the opposite shores of Pomona, near Stromness, or again when standing, as we did, upon the low, small island of Gremsa, the succession is unmistakeably exhibited. Observed in all these ways, the flagstone-rocks of Caithness, occupying low cliffs and terraces, are seen clearly to pass under and to be superposed by the reddish and yellowish sandstone of the Hill of Hoy, which, where it extends to the vertical maritime precipice on its north-eastern face, with its outlier the Old Man, has been ascertained to have a height of 1130 feet. I much regret not having explored this headland,

* The finest collection in Pomona is in the possession of the Rev. C. Clouston. (See Dr. Malcolmson's memoir, p. 348.) The traveller will find, in the excellent and comfortable inn at Stromness, kept by Capt. Flett, a little museum containing many of these ichthyolites.

which well merits a careful examination. I am not aware that any geologists, except Hugh Miller and Dr. Malcolmson, ever visited it*; and they were not able to detect any fossils in the sandstone of such great thickness, all of which, however, they clearly recognized to be (as indeed I had ascertained it to be many years before) younger than the Caithness flags. Though much affected by vertical fissures, the beds of the overlying sandstone are clearly seen to be very gently inclined to the N. and N.N.E., in conformity with the underlying flagstones.

The mere fact that sandstones of such great thickness overlie and graduate downwards into the Caithness flags, has necessarily had great influence in predisposing me to believe that other sandstones, apparently occupying a like position on the south side of the Moray Firth, are also of the Old Red age. This point will be considered in the following memoir.

On disembarking on North Ronaldsha, the northernmost of the Orkney Islands, we found that the flagstone series was still persistent; and, though we detected no fishes in our cursory examination, we found there a few fossil plants similar to those of Caithness.

Judging from the uniform character of the cliffs which we constantly passed near to in other islands, such as Rowsha, Stronsha, Shapinsha, and Eda, I infer that the chief stony masses of all the islands, seldom rising to more than 200 feet, are referable to the Caithness flags, though it is probable that the fine building-stones of the two last-mentioned islands, which are of light-yellow and whitish colours, belong to the upper member of the series, or that which we examined in Dunnet Head.

On the whole, however, and judging from the hard and siliceous nature of the beds at North Ronaldsha, it would appear that the ichthyolitic and bituminous schists and flagstones, which have their maximum development in Caithness, Pomona, and the Southern Orkneys, part with many of their peculiar characters in their range northwards, just as I have already shown that they change in their eastward range into the north-eastern parts of Sutherland, between Reay and Sutherland. In the sequel, this change of petrographical composition will be still more dwelt upon when we follow these beds southwards into Ross-shire, and thence to the south side of the Moray Firth.

*Old Red Sandstone of the Shetland Islands.*—In the rapid glance I obtained of this extensive group of islands, I could attempt little more than the simple determination that the sandstones, long ago described by Dr. Hibbert as "transition" and "secondary," were prolongations of the Old Red series of the Orkney Islands†.

At Somburgh Head, the most southerly point of the main island jutting out between the indentations called the East and West Voe, is a noble vertical cliff 300 feet high, on the summit of which the

* It appears, from the preceding memoir, that Dr. Malcolmson examined this bold headland in some detail, but met with no fossils there (p. 351).

† They are now so marked in the Geological Maps of Knipe and Nicol.

lighthouse stands. The chief mass of the rock is a finely micaceous light-grey sandstone, in parts reddish, and weathering brownish-red with a slight dip to the E.S.E., or away from the older rocks, which range from the Fitful Head to the N.N.E.

In the more flag-like and thinner beds of this sandstone, and at the very summit of the rock on which the lighthouse stands, Mr. Peach and myself found numerous fragments of plants. Hence we had no hesitation in considering this sandstone, and a fine conglomerate which it contains, to be of the same age as the rock which we had left at North Ronaldsha in the Orkneys, and to be really a part of the Old Red series.

As we steamed forwards to Lerwick, the cliffs of Lumboga Head, Troswick Ness, No Ness, and the Isle of Mousa seemed to consist of thin-bedded rocks pertaining to the same series; and in passing close along the western shore of the Isle of Bressay, we saw that the strata were thrown over on a dome-shaped rock of red colour. This mass and the overlying grey beds near the centre of the island are evidently carried under the beds of sandstone constituting the promontory on which the Lighthouse is placed. These beds, of light-grey colour and much charged with mica, dip to the E.N.E. at about 30°, and in lithological character are not unlike some of those of Somburgh Head. They contain casts of the trunks and branches of trees, the stems of which are fluted and void of joints.

At Lerwick, which is just opposite Bressay, we visited the quarries on the shore to the south of the town, which have afforded a considerable number of those plants, including those brought to me some years ago by my friend the late Right Hon. H. Tufnell*. The sandstone in which these plants are imbedded is of a brownish-red colour, whilst under Queen Charlotte's Fort, at the north end of Lerwick, the rock passes down into a thick-bedded mass with a few rounded pebbles, almost a conglomerate.

Although the ichthyolites of the Caithness flags have not yet been discovered in the Shetland Isles, the existence of strata of this age in the environs of Lerwick is placed beyond a doubt, by the discovery, in flaggy beds, of the same little Crustacean (the *Estheria*) which occurs at Thurso and Kirkwall.

Again, judging from the superposition of the sandstones of the Bressay lighthouse to a great inferior mass of rocks, there can be little doubt that these, as well as the plant-beds of Lerwick, pertain to the younger portion of the Old Red Sandstone †.

On inspecting several specimens which a quarryman had collected, one of which was nearly 5 feet long and 6 inches broad, it was clear that none of these plants possessed joints, as already noticed by Dr. Hooker ‡. They were simply long fluted stems without any

* Quart. Journ. Geol. Soc. vol. ix. p. 49.

† In his new map, Professor Nicol has accurately distinguished the Old Red of the east coast of Scotland from the much older Cambrian rocks of the west coast; and in his Geological Map of the British Isles, Mr. Knipe had also properly extended the Old Red along this portion of the Shetland Isles.

‡ Quart. Journ. Geol. Soc. vol. ix. p. 49.

transverse division whatever, and could not, therefore, I presume, be referred to *Calamites*. They are unlike any Carboniferous plant ever discovered, and on that account also are, in all probability, to be grouped with the plant-bearing Upper Devonian beds of Saalfeld in Germany and other places.

*General View of the Old Red or Devonian Rocks**.—The method of grouping the Old Red Sandstone deposits of Caithness, the Orkneys, and the north-eastern counties of Scotland, as above described, is in accordance with the tripartite division of their geological equivalents, the Devonian rocks of Devonshire, Belgium, and Germany. Referring to the Table of Classification published in 'Siluria,' I would here also indicate how unanswerably the zoological contents of the Devonian rocks of Russia (*i. e.* of deposits lying clearly between the uppermost Silurian and the lowest Carboniferous stratum) sustain my belief that the Old Red of Scotland and Herefordshire is the equivalent of this intermediate group on the continent of Europe. Proofs of the intermingling, in the same beds, of the sea-shells of the Devonshire limestones, with species of fishes identical with those of the Scottish Old Red Sandstone (the identity being determined by Agassiz), were first given in the work 'Russia and the Ural Mountains,' and were, I then presumed (1845), sufficient to demonstrate the truth of my inferences. Perceiving, however, that scepticism still partially prevailed on this subject, and that, Russia being far off, the statement of my associates and self had not made such an impression as the facts called for, I wrote to my friend Colonel Helmersen, who has given much attention to the stratigraphical arrangement and zoological contents of the Devonian rocks of Russia, and, referring to the recent admirable publication of Pander, I requested him to inform me distinctly to what extent the ichthyolites of the Old Red Sandstone of Scotland were commingled in Russia with Devonian mollusks. His answer was clear and decisive, in assuring me that there are many places, besides those seen by my associates and self, where the marine mollusca of Devon and the Boulonnais are mixed up with Scottish species of Old Red ichthyolites.

The lowest known Devonian strata in the north of Livonia, and thence ranging into the Government of St. Petersburg, repose transgressively upon various members of the Silurian rocks. Thus, in the Isle of Oesel, as described in a memoir recently read before this Society†, the uppermost Silurian rocks of the Isle of Oesel are shown, from the shells they contain, to be perfect representatives of the Ludlow rocks of England. With these are associated portions of many new genera, in addition to the *Onchus* and *Thelodus* of those British Upper Ludlow rocks; and with them two new species of the *Cephalaspis* have also been shown to occur. Thus far the physical and zoological relations of the uppermost Silurian rocks of Russia are in accordance with those of the typical region of England. Whilst, however, the latter affords evidence of a complete and unbroken transition upwards into the overlying Old Red, the same

* See Tables at pp. 437–439. † Quart. Journ. Geol. Soc. vol. xiv. p. 48.

intermediate zone is wanting in Russia*, the lowest Devonian or Old Red stage being there absent.

In Russia the lowest Devonian stage consists of the sandstones and shales which contain the fossil fishes of the north of Livonia, and those of the environs of Dorpat and of Tellin on the Lake of Rustuck. The fishes of this zone are those which Asmus first described (including the great *Asterolepis*), and of which Pander has in the last year given a more detailed and extensive account, and with that genus we now also have there the well-known *Coccosteus* of the north of Scotland. These beds graduate upwards into dolomitic limestone and shale richly charged with Mollusca, which in Germany, France, and elsewhere are recognized as middle and upper Devonian types,—the most frequent being *Spirifer Archiaci*, *Sp. Anosoffi*, *Productus productoides*, *Terebratula Livonica*, and abundance of Encrinites, &c. Now, in the very same beds with these sea-shells, corals, and crinoids, we find the *Holoptychius Nobilissimus*, and many of those fishes which are characteristic of the central and upper portions of the Old Red Sandstone of Perthshire in Scotland; in short, fragments of such ichthyolites are often found in hand-specimens, intimately mixed up with the above-mentioned mollusks, and in localities widely separated from each other, in several Governments of Russia. By this intermixture, it is demonstrated, that the theory, partially indulged in, of the freshwater origin of the Old Red ichthyolites is quite untenable. The uppermost Devonian stage of Russia, whether composed of red or whitish soft sandstone, or of greenish marls, as on the Priutchka River in the Valdai Hills, where I have examined it, and where it underlies conformably everything carboniferous, is laden with remains of ichthyolites, three of which are also identical in species with the fossil fishes of the Old Red Sandstone of Scotland and different from any known in the Carboniferous series. These are the *Holoptychius Nobilissimus*, *Glyptosteus favosus*, and *Diplopterus macrocephalus*. Judging, therefore, from the organic remains alone, we see that the lowest British zone, or that with *Cephalaspis* and *Pteraspis*, *Pterygotus*, and *Parka decipiens*, is wanting in Russia. There, the inferior strata, or those containing *Coccosteus*, *Dipterus*, *Asterolepis*, &c., represent the Caithness or central zone of our country; whilst the superior Russian members are equivalents of the higher portions of the Old Red Sandstone of Scotland and the limestones and slates of Devonshire, since they unite the fishes of the former country with the sea-shells of the latter. A reference to the work, 'Russia and the Ural Mountains,' and to the 'Fishes of the Old Red Sandstone' of Agassiz, suffices indeed to establish the correctness of this view, now that we know what is the real stratigraphical base of the British Old Red Sandstone; for all the species mentioned in other publications as common to Britain and Russia (to the number of twenty-one) occur in the middle and upper strata only of the Old Red of our own country†.

* See 'Siluria,' new edition, p. 384.

† Tables accompanying the following memoir will show the comparison

The proofs of the synchronism of these distant deposits through the identification of their included ichthyolites, and the intermixture of the sea-shells of Devon with the fishes of the Old Red of Scotland, entitled me to say of my associates and self, that "if our researches in Russia had led to no other result, they would, we conceive, have well repaid our labours*."

Nowhere in Russia is there, I repeat, a geological and zoological transition from the Upper Silurian, like that which is seen in Shropshire and Herefordshire. In this last-mentioned British tract the observer traces a gradual passage upwards from the bone-bed of the Upper Ludlow Rock with remains of a few peculiar fishes into the Tilestones in which the genus *Cephalaspis* first appears, but still associated with some Silurian mollusks, whilst in the beds immediately overlying we have the *Cephalaspis Lyellii*. The total absence of that genus, or, indeed, of any of the types of the Lower Old Red of England, Forfar, and Perthshire, in the lowest Devonian of Russia, when coupled with the fact that the Russian ichthyolites belong to the middle and upper zone of the series, is in perfect harmony with the above-noticed physical break.

*Newer Red Sandstone of the West Coast of Ross-shire.*—Professor Nicol having recently described† a Newer Red Sandstone as covering unconformably the higher inclined beds of the older conglomerates and sandstones on the shores of Loch Greinord, as first observed by Macculloch, let me add the notice of this deposit, which I take from my note-book of 1827. On reaching the shore of Loch Greinord, Professor Sedgwick and myself found three small headlands to be composed of a newer red sandstone separated from each other by sandy bays. The lowest beds are conglomerates and marls, which near Udrigill Head repose upon highly inclined (in parts nearly vertical) beds of older conglomerates and sandstone that form points protruding through the newer strata.

The lower conglomerate (now ascertained to be of Cambrian age) is overlaid by micaceous red sandstone and marls with greenish-white blotches, often of circular shape, whitish gritty beds of incoherent red sand, and other beds of conglomerate, the uppermost bed visible near the burying-ground being red sandstone with calcareous veins and red marl. Looking at the incoherent character of the sands and marls, which there occupy the sea-board for about two miles, and knowing that the conglomerate and grits with Lias fossils, as I had observed in the previous year, occur at no great distance on this coast of Ross-shire, and also that these Lias beds are underlaid by a red sandstone, my associate and self, without publishing the details of our note-book, gave it as our belief that the soft sandstone and marl of Loch Greinord belonged to the New Red Sandstone.

But this our old inference is scarcely to be relied on; for at that

between the British and Russian deposits, and the genera of ichthyolites which characterize each division of the Old Red or Devonian rocks.

* See 'Russia in Europe,' &c., vol. i. p. 63.

† Quart. Journ. Geol. Soc. vol. xiv. p. 167.

day we were necessarily unacquainted with the numerous ages during which the red sandstones and conglomerates of Scotland had been accumulated. It has, in fact, been ascertained that the conglomerate and sandstone of the West Highlands, which then passed for Old Red Sandstone, is of Cambrian age, and hence it follows that the red deposits lying unconformably upon those rocks may belong to the Old Red as well as to any other overlying deposit.

Of the Scottish red sandstones and conglomerates we may now indeed reckon the following:—

1st. Cambrian, or that of the N.W. Highlands.

2nd. Great Lower Silurian conglomerates of Ayr and Wigton.

3rd. Old Red base, underlying the Caithness Flags.

4th. Old Red summit, overlying the Caithness Flags.

5th. Carboniferous varieties.

6th. Permian conglomerates and sandstones of the S.W. of Scotland—Dumfries, Ayrshire, and the Isle of Arran.

7th. Red and green marls and sandstones, supposed to be of Triassic age, as seen in small detached portions.

*Lias and Oolitic Deposits.*—These Secondary deposits, which, as is well known, occupy large breadths in the Hebrides and are more sparingly distributed along the N.E. of Scotland, are now much better known than when I first endeavoured to make English geologists conversant with them by comparing them with their best types in England *. They will be again alluded to in the following memoir.

The late Hugh Miller has since expatiated on their fossil contents and peculiarities on both shores of the Highlands; whilst the breccias of the Oolite of Brora near Helmsdale have afforded to his scrutiny a multitude of beautiful fossil plants, which complete the resemblance of these northern deposits to their equivalents on the east coast of Yorkshire. The intercalation of freshwater beds in these Oolites, of which I only obtained a glimpse thirty years ago, has since been matured on the east coast by the late Mr. Robertson †, as well as by the late Edward Forbes on the Isle of Skye ‡. As respects the Liassic and Oolitic succession of the Hebrides, Mr. Geikie § has recently much improved our knowledge of the relations and boundaries of all the rocks in parts of the highly diversified Isle of Skye.

These subjects are indeed beyond the gist of the present memoir, and they are here merely touched upon in order to unite in one general view the whole of the ascending order of all the stratified deposits which really exist in the Northern Highlands.

Lastly, above all these lie those grand superficial accumulations of drift and huge erratic blocks, which, whether studied with reference to their glacial origin, or as connected with raised beaches of different levels, open out some of the most exciting subjects with which the geologist can grapple; they are, however, unconnected with my present object.

* See Trans. Geol. Soc. Lond. 2nd ser. vol. ii. p. 293.
† Proceed. Geol. Soc. vol. iv. p. 173; and Quart. Journ. Geol. Soc. vol. iii. p. 113.
‡ See Quart. Journ. Geol. Soc. vol. vii. p. 104. § Ibid. vol. xiv. p. 1.

## EXPLANATION OF PLATE XIII.

*Fossils from the Limestone of Durness.*

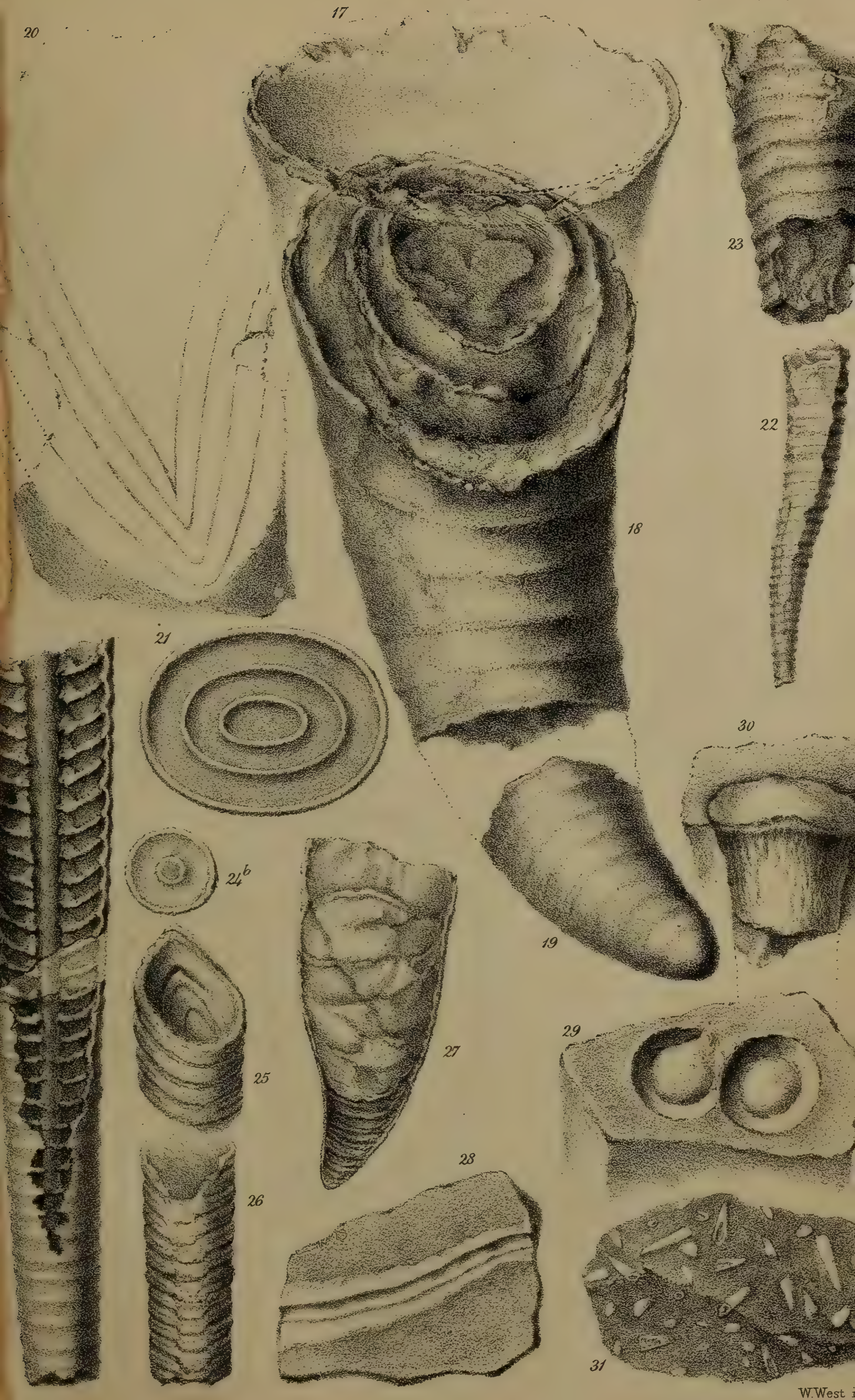
Fig. 1 *a. Maclurea Peachii*, Salter. Under or flat face, with the operculum added (1 *b*) to show its normal position.
Fig. 2. —— Upper or convex side of another specimen.
Fig. 3. —— Restored outline, seen from the front, with the operculum in position.
Fig. 4. —— Operculum, upper view.
Fig. 5. —— Operculum, viewed from within.
Fig. 6. Operculum of *M. Logani*, Salter. For comparison. In these figures, *a* is the straight lower edge; *b*, the umbo; *c*, the inner lower angle; *d*, the upper angle.
Figs. 7, 8. *Murchisonia gracilis*, Hall; var. *gracillima.*
Figs. 9, 10. *M. angulocincta.*
Fig. 11. *M. bellicincta*, Hall?
Fig. 12. *Ophileta compacta*, Salter. *a*, the lower face; *c*, the upper concave face; *b*, the convex dome-like cast of the upper surface.
Fig. 13 *a. Pleurotomaria Thule*, Salter. A portion of the surface, 13 *b*, magnified twice.
Fig. 14. *Orthis striatula*, Emmons. *a*, dorsal valve; *b*, a portion of the same magnified.
Fig. 15. —— Dorsal valve.
Fig. 16. —— Ventral or convex valve.
Figs. 17–21. *Piloceras invaginatum*, Salter. Fig. 17 is a specimen of a nearly perfect mouth, drawn behind the abraded specimen, fig. 18, which shows the concentric septa on the rough section, and is obscurely annulated on the outside; fig. 19 is the conical curved tip; fig. 20 shows a section of the cap-like septa in a fractured specimen; fig. 21 gives a transverse view of another specimen, showing three concentric septa.
Fig. 22. *Orthoceras vertebrale*, Hall? or young of *O. bilineatum*, Hall? Compressed and bent specimen.
Fig. 23. *O. vertebrale*, Hall?
Fig. 24 *a. Orthoceras mendax*, Salter. Broken, and showing the subcompressed siphuncular tube; 24 *b*, transverse view of concave septum with siphuncle, from near the smaller end.
Fig. 25. *Orthoceras undulostriatum*, Hall. Interior view with angularly bent septum.
Fig. 26. —— Front (or ventral?) view of another specimen.
Fig. 27. *Oncoceras*? undescribed species. A very doubtful specimen.

*Fossils from the Quartz-rock and Shale.*

Fig. 28. Annelide-tube (*Helminthites*), or trail.
Fig. 29. Double burrows (*Arenicolites*) in quartz-rock.
Fig. 30. —— Side view of another specimen, showing the contents of the burrows, roughly striated in a vertical direction.
Fig. 31. *Serpulites*? *M'Cullochii*, Murchison. In a mass of sandstone. These thick, short, free annelide-tubes are very common in the quartzose sandstones of Durness.


Tuffen West lith. ad nat.

LOWER SILURIAN




SILS FROM DURNESS

Tuffen West lith. ad nat.

W West imp

LOWER SILURIAN FOSSILS FROM DURNESS

## NOTICE.

Plate XII., consisting of a Geological Map of the Highlands, will appear in a future number of the Journal, as mentioned in the foot-note at p. 359.

DECEMBER 15, 1858.

The Rev. J. H. Austen, Ensbury, Dorset, The Rev. Alexander Maclennan, M.A., Rectory, Newington Butts, Surrey, John Sharp, Esq., of the Inner Temple, Barrister-at-Law, Tunbridge Wells, Henry Christy, Esq., Victoria Street, Westminster, and Joseph Paull, Esq., Moor-master, Aldstone, Cumberland, were elected Fellows.

The following communications were read:—

## 1. *On the* SANDSTONES *of* MORAYSHIRE (ELGIN, *&c.*) *containing* REPTILIAN REMAINS; *and on their Relations to the* OLD RED SANDSTONE *of that Country.*

By Sir RODERICK I. MURCHISON, G.C.St.S., F.R.S., V.P.G.S., &c.

INTRODUCTION.—In the preceding memoir the whole succession of the inferior crystalline and stratified rocks having been indicated, the triple arrangement of the Old Red Sandstone in an ascending order was shown to consist of a lower red sandstone and conglomerate, of a central deposit—the grey Caithness Flags, and of certain overlying sandstones, occasionally red, but of prevailing yellowish colour.

In this manner the whole of the Old Red series (or the equivalent of the Devonian rocks of other countries) is exhibited in the Orkney Islands, Caithness, and Easter Ross.

The lower division of the series in those tracts has not (see above, p. 400) afforded any of those fossils (the *Pterygotus*, *Cephalaspis*, *Pteraspis*, or *Parka decipiens*) which characterize the lowest Old Red of Forfarshire, Perthshire, Shropshire, and Herefordshire: the middle division (or Caithness Flags) is abundantly characterized by ichthyolites and the small crustacean *Estheria*: the third, as known to the north of the Moray Firth, has afforded, as yet, certain terrestrial plants only, which, approaching to the Carboniferous types, are forms hitherto unknown in any true Carboniferous deposit.

In following this natural physical group westwards along the north coast from Caithness into Sutherland, or northwards from the Orkneys into the Shetland Isles, its bituminous flagstone or central portion is seen to thin out. Such is also particularly the case in the southern extension of the group; which we proceed to consider.

Thus, after passing along the east coast of Sutherland, where the lower member only is visible, it is already important to remark, in reference to what is afterwards to be noticed on the south side of the Moray Firth, that at Dornoch, where the stone is quarried on the sea-shore, it is of a decided yellow colour; whilst there, and also near Tain, such yellow sandstones, which are largely used for building-purposes, graduate downwards into and are fairly interlaced with the Old Red Sandstone*.

* The detailed relations of the Red and Yellow Sandstone in the environs of Dornoch and Skibo Castle are much obscured by accumulations of gravel, forming remarkable ridges like the "åsar" of Sweden.

In the long narrow promontory of Tarbet Ness, to the E. of Tain, described in 1827 by Sedgwick and myself, the lower old red sandstone, resting upon the gneissose, granitic, and felspathic rocks of the Sutors of Cromarty, is followed on the north by a zone with ichthyolites, representing in miniature the great expanded masses of the Caithness Flags; and it is this zone which afforded to the scrutiny of Hugh Miller not only many Caithness forms, but also the *Coccosteus* and other types of the deposit which he was the first to describe. In this promontory, also, which juts out immediately opposite to the coast of Moray on the opposite side of the Firth of that name, the sandstones into which the central member of the Old Red passes upwards are of light yellowish colours, and on these stands the Tarbet Ness Lighthouse*. They are, in fact, an eastern portion of the yellow sandstones of Dornoch Firth and Tain (see p. 398).

In the other and interior parts of Ross-shire the central or ichthyolitic zone becomes still more attenuated, being visible in one district only, or Strathpeffer; but, although not detected in the banks of the Connan or the Orron, or in the Black Isle, where the sandstones and conglomerates are covered by much drift and laid bare at intervals only, it is probable that a feeble representative of the Caithness Flags may some day be discovered, inasmuch as in the eastern extremity of Inverness-shire, and not far to the S.E. of the town of Inverness, these bituminous schists recur in small dimensions at Inches, as pointed out to Sedgwick and myself by Mr. George Anderson. Thence the zone is traceable at intervals eastwards through Nairnshire into Moray; and at Lethen Bar and Clune it contains argillo-calcareous nodules, which afforded to the researches of Dr. Malcolmson and Lady Cumming Gordon the well-known fossil fishes described by Agassiz.

Now, although these fishes are essentially the same as those of Caithness, we already see how the great central deposit of flagstone has dwindled away to a mere stratum.

From this point the Old Red group, trending from W.S.W. to E.N.E., and dipping away to the N.N.W. usually at low angles, reposes on the flaggy micaceous gneissose rocks with granitic intrusions.

As the group is much denuded, as well as obscured by drift in its course through Nairnshire and Morayshire, it is not surprising that the slender nodular fish-zone or representative of the Caithness flags should be so rarely detected. The Lower Sandstone or Conglomerate is also of much less dimensions than in the northern counties of Caithness, Sutherland, and Ross. The River Findhorn in its course from south to north, on to Forres and the Moray Firth, exposes on its banks the best succession.

But, before I proceed to consider the adjacent tract around Elgin into which the strata seen upon the Findhorn are extended, it is essential that I should do justice to the other observers who, between the period when Professor Sedgwick and myself first rambled over this country and the present day, have thrown light upon its structure.

* See Trans. Geol. Soc. Lond. 2nd ser. vol. iii. p. 150, pl. 14. fig. 4.

With the exception of Mr. George Anderson of Inverness, who made known to Professor Sedgwick and myself various geological phenomena in the North, the next geological inquirer into the structure of Morayshire was the late Dr. J. Malcolmson, a native of that county and a medical officer of the East India Company's service, who, being on leave of absence in the years 1838 and 1839, prepared a most able sketch of the tract, including the discovery of many remains of fishes. In this sketch, which was read before the Geological Society, 5th June, 1839, Dr. Malcolmson followed Professor Sedgwick and myself, after an interval of eleven years, in grouping the yellow sandstones and cornstones of Elgin, as we had done, with the Old Red Sandstone. But my lamented friend did much more. He found many fossil fishes unknown to my associate and myself in our rapid transit; and his memoir was, as I can testify, a most valuable record in showing not only the relative position of the ichthyolites of the formation—and thus of use to Agassiz in his description of them,—but also in proving the natural connexion between the different members of the Old Red series.

Owing to the circumstances explained in the prefatory note at p. 336, Dr. Malcolmson's memoir was not printed,—an able abstract of it, prepared by Mr. Lonsdale, having alone been published. The Rev. G. Gordon*, who has had possession of a copy of this memoir, gave to the world the chief parts of it, as well as extracts from letters, in a late Number of the Edinburgh New Philosophical Journal.

In the autumn of 1840 I revisited the spots around Altyre and on the Findhorn, which through the discoveries of Dr. Malcolmson and Lady Gordon Cumming, and the publications of Agassiz, had then come prominently into notice; and, though I published no account of my journey, it was then that I more than ever satisfied myself that the red sandstones and conglomerates and overlying yellow sandstones and cornstones formed one natural series. I then found that the same ichthyolites as those of Caithness had been detected in a thin argillaceous zone which Professor Sedgwick and myself had considered to be the equivalent of the Caithness Flags in the tracts to the S.E. of Inverness. It was then also that I first saw fossil fishes at the Findhorn and at Scat Craig, south of Elgin; the latter under the guidance of Mr. G. Gordon.

Following Dr. Malcolmson, Mr. Patrick Duff, of Elgin, next published his work entitled 'Sketch of the Geology of Moray' (1849), as put together from twelve letters previously published in the 'Elgin Courant,' illustrated by a geological map prepared by Mr. Martin, of Elgin, who had even then discovered the Old Red fishes of Scat Craig, to the south of Elgin. The author of this work describes in succession the physical geography, and then the various deposits, in descending order, of which either certain debris or small patches

* In his able review of the proceedings in Morayshire, in which my friend the Rev. G. Gordon has taken a much more active part than he himself mentions, his chief object was to do justice to Dr. Malcolmson. (See Edinburgh New Philosophical Journal, vol. ix. p. 14, January 1859.)

exist—viz. limited areas of Wealden or Purbeck beds, and loose, scattered, or drifted remains of the Oolite, Lias, and Cornstones. Under these he places the older rocks of the district—the Yellow and Red Sandstones; for, unlike other authors, he did not group the Cornstone with the Old Red Sandstone: this memoir was illustrated by ten plates of fossil remains.

It is unnecessary that I should here advert further to the overlying formations containing Wealden or other fossils of the Oolitic series, since they have been found in mere patches only, always overlying the rocks under consideration, and imbedded in argillaceous and incoherent strata with thin shreds of limestone, the whole entirely distinct from the underlying cornstones and yellow and red sandstones on which they repose. In fact, the Oolitic Wealden patch at Linksfield* rests at once on hard siliceous cornstone, the upper surface of which has been powerfully eroded, showing that there is no sort of natural connexion between these two deposits.

The discovery of Reptilian remains in certain light-yellow sandstones was made subsequently to the publication of Mr. Duff's work. The single specimen with the impression of scutes of *Stagonolepis*, found at Lossiemouth, and which Agassiz named after Mr. Robertson, was first in the possession of Mr. Duff; so also was the specimen of *Telerpeton*, found in the Spynie quarry, and, as is well known, transmitted by that gentleman to London through Capt. Brickenden. The short memoir by the last-named gentleman, which is published in our Journal†, is very correct in defining the exact position in which the *Telerpeton* was found; and the description of the animal by Dr. Mantell‡, which accompanies it, completes this brief sketch of the progress of discovery in the Old Red strata and fauna around Elgin.

*Succession of the Stratified Rocks in the Northern part of Morayshire.*—Let us now proceed to consider the order in which the mineral masses of Moray are collocated.

The best natural sections of the whole series of strata of which the Old Red Sandstone mainly consists in this part of its range, are seen upon the banks of the Findhorn River. To the south-west of Altyre (the seat of Sir W. Gordon Cumming), the crystalline rocks, in the condition of quartzose and gneissose flags, which have been penetrated by granite-veins, roll over on a partial axis, dipping both to the S. by W. and N. by E., and with a strike from E. by S. to W. by N.

Reposing on the crystalline rock, the following succession of strata is exhibited as you descend the Findhorn River to Cothall near Forres, the dip of the whole not exceeding 8° to the N.N.W.:—

*a.* Lowest beds, shaly and thinly laminated red and grey grit, with black and white mica, and occasional concretionary blotches of green earth. *b.* Angular conglomerate, composed of both large and small fragments of the adjacent

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* See Dr. Malcolmson's note, Proceed. Geol. Soc. vol. ii. p. 669; and Capt. Brickenden's Section, Quart. Journ. Geol. Soc. vol. vii. p. 291.

† Vol. viii. p. 97. ‡ Ibid. p. 100.

quartzose gneiss cemented in a reddish- and greenish-white paste and interlaced with red- and green-spotted marly sandstone. *c.* Reddish fine-grained sandstone. *d.* Marly grit, with some pebbles and many concretions of red and green marl or shale (this is seen to have a thickness of 60 feet). *e.* Coarse conglomerate, of very variable thickness, composed of fragments of the crystalline rocks, varying from grains of sandstone to 7 or 8 inches in size, the whole in a calcareous cement with calc-spar. *f.* Yellowish sandstone. *g.* Deep-red sandstone. *h.* Yellow sandstone, occasionally reddish. *i.* Sandstone of pinkish-white colour. *j.* Cornstone of Cothall*.

Whilst such is the general section of strata clearly exposed in a conformable succession as you descend the Findhorn River, a single vertical section at the cliff called the Ramphlet, on the right bank of the stream, presents the following order from the base upwards:—

| | Feet. |
|---|---|
| Pinkish sandstone, alternating with deep-red or purplish shale and blotches of deep-red and green colours in a highly micaceous mass, with much black mica | 50 |
| Whitish and pinkish sandstone | 12 |
| Conglomerate of crystalline rocks in a calcareous cement | 35 |
| Greenish-white and reddish sandstone | 50 |
| Dark-red sandstone | 40 |
| Yellowish sandstone | 30 |
| | 217 |

It is chiefly beneath these last-mentioned red, green, white, and yellow sandstones that many fossil fishes were found by Dr. Malcolmson and Lady Gordon Cumming at Clune, Lethen Bar, and Altyre †, both in nodules in argillaceous shale, and in a thin flaglike band of yellow and deep red colour,—the beds, as seen in the burn near Altyre, splitting into rhombic flags, and resting at once on the lowest conglomerate and sandstone. In these ichthyolitic beds, evidently representing the Caithness Flags, no *Holoptychii* are found. Owing to the vast denudation which the lower tracts of Morayshire have undergone between the meridian of Altyre and Forres on the west and that of Birnie and Elgin on the east, it is impossible so to follow any one band of rock as to mark its variations and changes along the strike of the strata.

Already, however, in Ross-shire, and still more on the Findhorn banks, it has been shown that light-yellow colours occur throughout the group; so that on reaching Elgin we find that the red beds are chiefly seen in the lower parts of the section, and that, with some partial alternations of red rock, the mass of the sandstone which is visible is of a light-yellow colour (occasionally under the chisel working as a white freestone).

* The upward continuation of the series to the north of Cothall is obscured by drift and gravel, and the subsoil of the whole tract between Forres and the sea is hidden under dunes of blown sand, forming low hills. Light-coloured sandstone crops out, however, in the Water of Nairn at the town of that name. (For a graphic account of this district, see 'Anderson's Guide to the Highlands.')

† The fossil fishes which were found at Clune, Lethen Bar, Altyre, &c., were, according to Agassiz's description, *Pterichthys latus*, *P. Milleri*, *P. productus*, *P. cornutus*, *P. major*; *Coccosteus oblongus*, *C. maximus*; *Cheiracanthus microlepidotus*; *Diplacanthus striatulus*, *D. longispinus*; *Cheirolepis Cummingiæ*; *Osteolepis major*; *Diplopterus macrocephalus*, &c.

Fig. 1.—*Section from the Crystalline Rocks across the Old Red Sandstone to the Yellow variety of the same at Elgin.* (Length about 11 miles.)


*a.* Micaceous and flag-like gneiss, penetrated by granite (*). *b.* Conglomerate (Scat Craig, &c.), with ichthyolites. *c.* Yellowish soft sandstone, with ichthyolites. *d.* Mottled cornstone, of dark-red and greenish colours. *e.* Coarse red conglomerate and sandstone, forming the cliff on the right bank of the Lossie above Birnie. *f.* Cornstone, much thicker than *d.* *g.* Reddish and yellow sandstone, with *Holoptychii*; passing up into *h*, or the yellow and white freestone of the Quarry-wood Ridge at Elgin. N.B. Owing to the amount of drift (debris of all sorts), δ, which obscures the surface, the relations of the sandstone, *h*, to a similar sandstone at Findrassie and Spynie, containing reptiles, have not yet been accurately detected.

In making an ascending geological section (see section, fig. 1) from the edge of the crystalline rocks about five miles south of Elgin, and passing by that town to Lossiemouth and the coast-ridge which extends eastwards from that place by Covesea to Burgh Head, the following phenomena present themselves. In the hills east of Dollas, the older or crystalline rocks are finely laminated, quartzose, micaceous, and gneissose flagstones, splitting to the thickness of tiles, containing some white quartz-veins, with layers of pinkish and greyish colours alternating, and with northerly dips varying from 25° to 45°. This crystalline rock is unconformably overlaid by a hard grit, surmounted by a coarse red conglomerate with interlacing marly beds, as in the sections described near Altyre. The Falls of the Shoggle Burn, to which I was conducted by my friend the Rev. G. Gordon, exposes such junctions clearly. Brick-red breccia or conglomerate, with way-bands of red marl, follow as you advance into the vale watered by the Lossie; and these beds are immediately surmounted by soft yellow grits and sandstones in which fish-scales and other fossils occur (*Bothriolepis*, &c.)*.

* These fossils, in a similar matrix, also occur, according to Mr. G. Gordon, on the side of the Buinach Hill, halfway between the Shoggle Burn and Pluscardine Priory.—June 1859.

Though not on the same line of section, the conglomeratic beds of Scat Craig, which lie a little to the east, are to be referred to this member of the series, *i. e.* to strata of a rather younger age than the lowest fish-beds of Lethen Bar, Clune, &c., or the Caithness strata. At Scat Craig the conglomerate is chiefly of greenish colours, though red in parts, and is bound together with a calcareous cement and a sandy matrix of green, red, grey, and yellow colours, such masses being arranged in flattened concretionary forms.

There are, in fact, passages from fine grey grit to pebbly conglomerates, both angular and round, with which white calc-spar is disseminated. The whole of this mass, like the strata upon the Findhorn, dip at very low angles only to the N. and N.N.W.

The interest which specially attaches to the fossil fishes found at Scat Craig is, that, whilst the *Pterichthys major* and other species of that genus, as well as the *Asterolepis*, are common to Caithness and the west of Moray (Lethen Bar, Clune, Altyre, &c.), there are other forms, such as the *Dendrodus latus* and *D. strigatus*, *Lamnodus*, and *Cricodus*, which, as well as the *Asterolepis Asmusii*, are common in the Old Red of Russia, where I have myself detected them. The Scat Craig beds offer, besides, zoological evidence of an ascending order from the Caithness group into the superior or Holoptychius-band so common in Perthshire and Fifeshire; for associated with the true Caithness fishes above mentioned we meet (for the first time in ascending order) with the *Holoptychius Nobilissimus*, Ag., of Perthshire and the south of Scotland.

There is a union, therefore, in this one mass of conglomerate, of genera which in other places mark the central and upper members of the series. Moreover, it is not to be forgotten that in the overlying beds near Scat Craig the red conglomerate and sandstones first become foxy yellow, and then pass into the ordinary yellow and light-coloured sandstone in which the *Holoptychius* is, as far as I know, the chief fossil, the other and older forms having disappeared.

We shall afterwards see how the lower and central sandstones and conglomerates, expanding largely in their range to the east, again exhibit the Caithness group of ichthyolites at Tynet, Dipple, and Gamrie.

In the meantime let us continue the transverse ascending section of the Lossie. Advancing from the yellowish grit and sandstone with remains of fishes, after a considerable amount of denudation and consequent obscuration by gravel, a coarse red conglomerate containing blocks of some size is seen to occupy strong beds, and to be of great thickness, on the right bank of the stream, above the Manse of Birnie,—all the strata being inclined to the N. or N. by W.

Judging, however, from the generally uniform and consistent dip of all these beds, I satisfied myself that one of the mottled red and greenish-grey concretionary masses, pointed out to me by Mr. Gordon, must be considered to lie beneath the Birnie conglomerate, and range along a tract which in the bed of the Lossie has been denuded.

In fact, the tendency to form a cornstone, or concretionary calcareous rock, has been already adverted to, as showing itself in the

Findhorn section; and hence I place the first or lowest cornstone of the Elgin tract (at the spot called Foths) in the generalized transverse section, fig. 1. Indeed, the rock there is like many of the small concretionary cornstones of Herefordshire. In advancing to the north, or towards the town of Elgin, from the sloping higher grounds where the lower beds are exhibited, the plain is so obscured that little is seen under the drift, except at two or three quarries of thick-bedded, massive, grey-coloured cornstone from which the drift has been removed, and which I believe to be a continuation of the calcareous band of the Cothall quarries on the Findhorn. If we judge from their very slight general inclination to N.N.W., these limestones must pass under the whole of the sandstone-ridge to the south of Elgin.

On reaching the parallel of Elgin the ground begins to rise in undulations, and consequently to expose here and there some rocks which, judging from their position and fossils, must belong to a higher division of the group than any portion to the north. Thus, at Bishop Mill, north of the town, the scales of the *Holoptychius Nobilissimus* are alone found in yellowish gritty sandstone (sometimes working under the chisel as a white close-grained sandstone), the beds being very slightly inclined to the N.N.W.

These rocks occupy, on the whole, a low wooded ridge extending to the Knock of Alves on the W.S.W.; and thus far, therefore, all is true Old Red Sandstone. It was towards the north-eastern summit of this ridge, or in the quarries west of Spynie Castle, that the cast of the *Telerpeton* was found; and Capt. Brickenden has fairly represented * how the sandstone, dipping to the N.E., seems to pass under the hard, concretionary, siliceous or cherty cornstone on which the old Castle stands. Again, where the ridge thickens in the meridian of Elgin, other remains have been found in the quarries of Findrassie. These, which are chiefly hollow moulds, and which Mr. P. Duff and the authorities of the Elgin Institution have kindly sent up for examination to the Museum of Practical Geology, have, under the skilful manipulation of Professor Huxley, given out solid casts representing the forms of teeth, vertebræ, and other bones, all of which, as Professor Huxley will show, belong to the Reptile *Stagonolepis Robertsoni*. Owing to its amorphous condition and to its relations being obscured by detritus, the massive rock of siliceous cornstone upon which the Castle of Spynie is built exhibits no absolute junction with the sandstone.

The surface being much covered by drift and the hills being all very low, there is some difficulty in determining satisfactorily the point which is, after all, the gist of the inquiry,—viz. whether the sandstone with reptiles (*i. e.* of Spynie and Findrassie) is really united with the sandstone, of the same colour, containing *Holoptychii*. This question, however, would seem to be answered in the affirmative, when we follow the Elgin ridge in its extension from east to west, by finding near its base red and yellow grits and marls, with the scales of *Holoptychii* and other fish-remains.

* Quart. Journ. Geol. Soc. vol. viii. p. 99, fig. 1.

Without quitting this ridge, the observer can scarcely doubt that the mass of the yellow and whitish sandstones are simply the conformable upward continuations of the true Old Red Sandstone, and that the succession is similar to that which is exhibited on the Findhorn River between Altyre and Forres. Thus, at Bishop Mill, immediately to the north of Elgin, the gritty sandstones, passing from red to yellow colours and containing scales of *Holoptychii*, so dip to the N. and by W. that, though the junction is hidden, they must infallibly pass under the beds with *Stagonolepis*, which at the Findrassie quarry apparently dip at the same low angle and in the same direction*.

According to my own observation such relations are indeed proved to exist by following the ridge from the Hospital Quarries to the west. At Newton, on the opposite side of the ridge to that occupied by the Bishop Mill quarries, as well as at Carden Moor, many scales of *Holoptychii* and other remains of fishes occur in reddish and grey pebbly grits associated with deep-red marly shale, some of which were sent to the Museum of the Geological Society many years ago by that close observer the late Mr. Alex. Robertson of Inverugie. Now, I satisfied myself, when in company with Mr. G. Gordon, that these red beds with ichthyolites form the lower part of the yellow sandstone ridge, which, whether it contains reptiles at its eastern end, or becomes a pebbly conglomerate towards its western extremity in the north of west, seems to be one and the same deposit.

In short, the red sandstone and pebble-beds with *Holoptychii* constitute the natural base of the yellow and white Elgin freestone, the summit of which, after all, is perhaps not more than 120 or 150 feet above the red fish-beds.

The most remarkable exposition of the strata on the summit of the Elgin ridge is seen at the Hospital quarries, where the sandstone is cut into to a depth of about 70 or 80 feet. The uppermost strata are hard and gritty, and only used as road-stones, the central mass affording the best freestone in beds of great thickness—fine-grained, slightly micaceous, of white and light-yellow colours, here and there inclining to pink. These beds rest upon softer and marly beds of light-greenish colours.

A plain of complete denudation, formerly much covered by water, and extending from Spynie Castle on the E.S.E. to near Lossiemouth on the W.N.W., is covered by much detritus, and separates the Elgin Hills from another low parallel ridge of similar yellow and whitish sandstone, which, also ranging from W.S.W. to E.N.E., extends from Lossiemouth by Stotfield and Covesea to Burgh Head. [The following section, fig. 2, may be considered as the northward continuation of the preceding one, fig. 1, p. 424.]

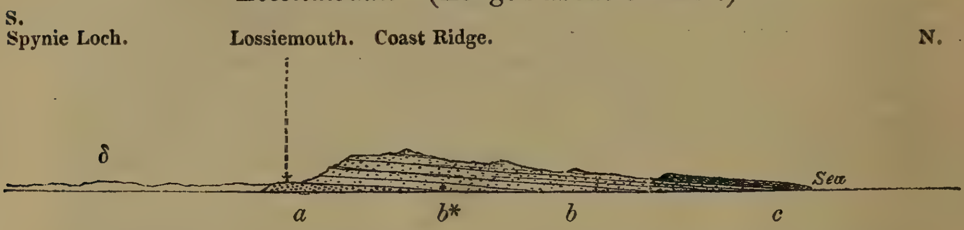
Along this coast-ridge, and for a distance of about six miles, numerous quarries have been opened out, one of which has afforded large bones of reptiles, and another numerous impressions of the feet and claws of such animals.

Having seen in the possession of Mr. Martin, the intelligent

* The Findrassie quarry was filled in, and out of use, when I was last at Elgin.

schoolmaster of Elgin above alluded to, a large bone which he had recently found in the sandstone quarries at Lossiemouth, he most generously presented it to me as a contribution to the Museum of Practical Geology. Being astonished at the state of preservation of this bone (all the specimens hitherto found being casts, whether the *Telerpeton* of Spynie or various curious undescribed forms in the Elgin Museum, including the scales of *Stagonolepis*), I lost no time in proceeding to Lossiemouth in company with my intelligent friend Mr. G. Gordon, to endeavour to find more bony relics: for my readers may well estimate the value I attached to such a bone as that which I had seen there in association with the huge scales of *Stagonolepis*, which, having been also found at Lossiemouth, had up to that moment been classed with Fishes.

Fig. 2.—*Section showing the position of the Reptiliferous Sandstone at Lossiemouth.* (Length about 3 miles.)




*a.* Laminated red and yellow sandstone (in the suburbs of Lossiemouth).
*b**. White and yellowish sandstone, with *Stagonolepis* and *Hyperodapedon.*
*b.* Yellowish sandstone, forming the east end of the Burgh Head, Coast Ridge.
*c.* Overlying cornstone on the sea-shore. *δ.* Drift, covering the plain.

To the north of the drift-covered low plain of Spynie, the lowest strata (fig. 2, *a*), which are seen behind the houses of the suburb of Lossiemouth, consist of finely-laminated soft shaly sandstone striped with deep-red and yellow colours; this band passes upwards into very thick-bedded yellowish and white sectile freestones (*b*), that are largely quarried on the side of a low cliff. It was in the lowest part of these (* in the section, fig. 2) that we detected several other bones, which, at the first aspect, seemed to be also those of reptiles; and these also, under the scrutiny of Professor Huxley, have proved to be portions of the *Stagonolepis*. These freestones, underlaid by red strata and surrounded by hard splintery sandstone (refuse of the quarrymen), present therefore precisely the same mineral succession as parts of the parallel ridge of Elgin; and in each, reptilian remains have been found. I must indeed avow, that it was this Lossiemouth section which most led me to class the yellow and white Reptiliferous sandstone with the Old Red, seeing that there is visible a perfectly conformable passage from red beds up into strata with reptilian remains.

The sandstones of Lossiemouth and Stotfield are further seen to be overlaid, in perfect conformity, by hard, thick-bedded, cherty, and cavernous cornstones (*c*) ranging down to the sea-shore, in which band thin veins of lead-ore are occasionally found; and thus the whole series is knit together by a succession of mineral repetitions, which, in the present state of my knowledge, make it impossible for me to disunite stratigraphically the reptiliferous sandstone from the yellow and red Old Red Sandstones with cornstones*. Nay, more, Mr. Gordon directed my attention to a reef of rocks exposed only at low water, where hard red flagstones (which I did not reach, but specimens of which I saw) re-occur, near Halliman's Scars.

On examining the coast-ridge, as extending from Lossiemouth by Stotfield, and particularly in its range from Covesea Lighthouse to Burgh Head, it is seen to exhibit several variations in structure. Thus at the Lighthouse the beds resume a pinkish tint; then, again, the celebrated Caves of Covesea (so much frequented by pleasure-parties), which have been excavated by the sea in lofty vertical cliffs, occur in softish yellow and white sandstone, and exhibit undulations by which the strata roll gently over to the south as well as to the north or seawards. This flexed arrangement pervades the whole of the promontory in its westward extension; for, on reaching the Clashan quarries, the beds are distinctly observed to dip both southerly and northerly, the latter dip being traceable inland, and constituting a long slope, which ranges from the highest part of the ridge (about 300 feet above the sea) down to the valley which lies between this coast-ridge and the Elgin Hills. This anticlinal is represented in the accompanying section, fig. 3.

Fig. 3.—*Section across the Coast Ridge at the Clashan Quarries.*


*a.* Quarries of Clashan, &c., affording Reptilian foot-marks. *b.* Overlying beds, as seen on the shore near Burgh Head, occasionally pebbly. *δ.* Drift of the plain extending westwardly to Spynie Loch.

Still further to the west, and where the promontory lowers to a narrow peninsula terminating in the point of Burgh Head †, the same axial tendency to folds and curvatures is exhibited along the shore. It is in one of the sandstone quarries of Cummingston, called the "Masons' Heugh Quarry," and on the estate of Major Cumming Bruce, M.P., that numerous impressions of the footsteps of reptiles

* I examined a similar cornstone with galena at Inverugie, situated nearly a mile inland or to the south of Cummingston, at least 200 feet above the sea, which, although no junction is visible, seems also to overlie the sandstone in which the footsteps occur.

† Antiquaries are generally agreed that Burgh or Brough Head is the Ultimum Pteroton of the Romans; and as such indeed it is named in an old map of Scotland by General Roy. In my last visit I inspected the ancient arched excavation and well in the sandstone rock, recently discovered and now again used as a well. There can be no doubt that the work is Roman, from the massive character of the steps, the figure of a bull, and other relics that have been found there. In subsequent ages, Burgh Head is supposed to have been a strong place of the Norsemen, whence its name of Burgh. See 'Anderson's Guide to the Highlands,' p. 350.

have been detected for some years *, and especially of late, many of the stones having been recently sent to Elgin to serve for the construction of the new railroad †.

On visiting this quarry of yellow sandstone, the beds of which are inclined to the N.N.W., and where footprints have been found for many years in different layers, and on seeing that there might be procured, with a little precaution, finer impressions than any we could then find, or than had been sent formerly to London by Capt. Brickenden (as fine, in short, as those I had seen on the premises of Mr. Alexander Young of Elgin, and which had been derived from this spot), I requested Mr. Gordon to secure some of the best examples from the proprietor of the quarries. This he has since done, and has transmitted to me many good examples of those impressions.

At Burgh Head, where they run out in a narrow promontory, the culminating point of which is about 70 feet above the sea, the yellowish sandstones are associated with strong hard beds containing pebbles of quartz and granite (an association which reminded me of the sandstone and conglomerate reefs of Embo, on the Dornoch Firth), the whole having a northerly dip at the prevalent low angle of 4° or 5°.

The parallelism and similarity of structure of the chief mass of the sandstones of the coast-ridge to those north of Elgin, and the existence in each of the same reptile (*Stagonolepis*), might alone lead to the conclusion that the one was simply a repetition of the other. Seeing the manner in which the beds of the coast-ridge fold over with a gentle dip to the south, they may indeed well be supposed to recur in the Elgin ridge, whether near Spynie Castle on the east or in its western prolongation to the Moor of Alves.

At the same time, it is to be inferred that some of the strata in the coast-ridge are higher in the series than any which are visible near Elgin. The pebble-beds of Burgh Head may, indeed, be local equivalents or repetitions of those of the Moor of Alves at the west end of the Elgin ridge; but the overlying cornstones of Stotfield or Lossiemouth, extending as they do upwards of a mile along the coast, and surmounting the reptiliferous sandstones (to say nothing of the red reefs near the Skerries), must be considered younger strata. The repetition therefore of such limestones, from near the base of the whole series at Foths (fig. 1, p. 424) to the environs of Elgin, and to those ledges on the coast which are every here and there apparent,

* Quart. Journ. Geol. Soc. vol. viii. p. 97.

† After my last inspection of this county, Mr. Beckles visited these quarries, and, carrying wood and carpenters to the spot from Forres (as he informed me by letter), directed the process of uncovering the foot-marked flagstones, and obtained many large and fine specimens. The Rev. G. Gordon informs me that footprints have been observed at the Clashan quarry of Covesea, and by Mr. Anderson, the original discoverer, at his intermediate quarry of Greenhow. In May last Mr. Gordon had the satisfaction of securing for the Elgin Museum, from Messrs. Smith and Fraser, a block, which had been quarried at Lossiemouth, and partly dressed for the step of a stair, on which there are footprints similar to those found at Mason's Heugh, &c. The footsteps are therefore now known at those three localities.—June 15, 1859.

is a lithological feature common to the whole series and strongly to be dwelt upon. It is, however, to be remarked that the cornstones of the shore to the west of Lossiemouth, and the patch at Inverugie, are much more cherty than those beds which, lying further to the south, occupy an inferior position. The uppermost or third zone of cornstone is indeed distinguishable from either of the others, in being highly mineralized and siliceous, containing veins of pure lead-ore, whilst the central cornstones are massive limestones, and the lowest (thin, small, and mottled red and green) concretionary earthy limestones; still they are all referable to varieties of cornstone. But, after all, the presence of cornstone is *per se* no proof that the sandstone in which it occurs is the Old Red Sandstone; for the rocks first described as cornstone by Dr. Buckland in parts of Worcestershire and Staffordshire were afterwards shown by myself to be of the Lower New Red age (or what I have since named Permian) *. (See 'Silurian System,' p. 55, pl. 37.)

Looking to the persistent strike of all these arenaceous deposits from their red bases to their yellow and white summits,—to their interlamination and association with cornstones at low and high levels,—to the ascent from the beds with Caithness fishes to the strata laden with *Holoptychii*, and from the latter into the upper or reptiliferous masses,—to the gentle undulations and low dips to which, from the base upwards, they all conform,—I was led to the conviction that, to however high a family of Reptiles the *Stagonolepis* might be referred, both the yellow sandstones of Elgin and those of the coast-ridge would seem to belong to the same geological group of strata as the underlying Red Sandstone.

In prolonging the survey from Morayshire into Banffshire, we find that the upper or yellow sandstones have been partially prolonged to the sea-coast only, and that in the interior, the deep-red sandstones and conglomerates represent the middle and lower parts of the series, which have recovered the large dimensions they possess in Ross-shire and the northern counties. On the banks of the River Spey vast thicknesses of deep-red sandstone and conglomerate (fine types of which are seen at the Bridge of Fochabers) are overlaid at Dipple and Tynet-burn (near the mill) by argillaceous courses with nodules containing certain fishes of the genera *Pterichthys*, *Coccosteus*, *Glyptolepis*, *Osteolepis*, *Cheiracanthus*, *Diplacanthus* †, &c., a complete Caithnessian assemblage.

Again, at Gamrie, near Troup Head, Aberdeenshire, where the central zone reappears on the sea-coast replete with the same group of fishes, the beds are seen to be underlaid towards the interior of the county by vast masses of deep-red sandstone and conglomerate. In that tract the yellow sandstones are no longer visible, being buried under the German Ocean.

* The reader who may refer to the 'Silurian System' will see, in the foot-note at p. 55, that in the first year of my survey I was misled by the mineral characters, and was disposed to consider those sandstones with cornstones to be of Old Red age.

† Fine specimens of these ichthyolites were presented to me by Mr. Alex. Simpson, of Holl, Tynet.

In the heart of the Aberdeenshire Highlands, near Rhynie and on the banks of the Bogie, the Rev. Alex. Mackay found in 1854 other fossil remains in Red Sandstone, some of which he submitted to the late Hugh Miller*. One of these objects, which he has transmitted to the Museum of Practical Geology, is unquestionably a fragment of a large stem of a plant, which measures 4 feet in length by 5 inches in width. It is nearly cylindrical, and is fluted irregularly near the pointed tip. No joints or nodes are visible as in Calamites; but the surface is coarsely striated. The striæ or ribs are too obscure to warrant us in placing this fossil plant in the genus *Columnaria* of Sternberg, which it most resembles†.

*Concluding Remarks.*—In still holding the received opinion, that the sandstones in which the *Stagonolepis* and *Telerpeton* occur belong to the uppermost member of the Old Red or Devonian group of rocks, it is necessary to meet the objections to this classification which may very naturally be made by persons who, not having examined the country, are solely influenced by the circumstance of reptiles of high organization being found in so ancient a deposit. Such reasoners (with whom my own progressionist tendencies predispose me to concur) may also suggest one local geological feature which appears to favour their hypothesis. Seeing that many Oolitic and Liassic fossils are spread over the surface of the lower portions of this tract of Morayshire, and that small patches of a few yards in dimension have even been stated to occur *in situ*, they may contend that these are the relics of strata which reposed upon the light-coloured sandstones, and that the latter may really represent a portion of the Lower Lias, or even Trias, in which reptilian remains are known to abound. But, as no strata of Lias have been detected *in situ*, and as the small patches with Oolitic Wealden fossils rest on the eroded surfaces of the cornstones and sandstones, there is nowhere an indication of any connexion between these fragmentary relics and the subjacent rocks. Again, it is to be recollected that all the Oolitic fossils of Moray occur either in dark shale or in loose drift, and that not a trace of these fossils is to be seen in the reptiliferous sandstones, which are of entirely different characters.

It may also be said that, although small relics or even debris only are left of these younger Oolitic deposits, we must not judge by the evidences on the south side of the Moray Firth, but repair to the tract of Brora and Dunrobin as well as to the shore of Ethie on the northern side of this great estuary, and there see if, in the diversified strata of Oolitic and Liassic age (all of which may once have extended to Morayshire), there are no rocks which can be assimilated to those

* Some of these are impressions, occurring in the argillaceous layers of the sandstone, and were at first taken for fucoidal and fern-like imprints; but Mr. Hugh Miller (as I am informed by Mr. Mackay) regarded them as the tracks of a Crustacean. An inspection of these very imperfect impressions conveyed to Mr. Salter the idea that they might have been made by the pectoral fins of fishes swimming in shallow water.

† Not having personally examined the tract in which Mr. Mackay resides (though I hope to do so next summer), I cannot pretend to decide upon the position which this plant occupies in the series of Old Red strata.

which contain the Elgin reptiles. Now, as those Oolitic and Liassic beds of Sutherland and Ross are perhaps better known to myself than to most other geologists, and as I have twice revisited them since I described them in the 'Geological Transactions' thirty-two years ago, I unhesitatingly affirm that in no one respect do they resemble the reptile-bearing sandstones of Elgin. The following reasons will place this inference clearly before the reader:—

1st. The Oolitic and Liassic strata in Sutherland and Ross are everywhere discordant to the strike, range, and dip of the Old Red Sandstone, whilst the yellow sandstones and cornstones of Elgin are (as has been shown) apparently conformable to the red sandstone with characteristic ichthyolites, on which they rest, and into which they graduate downwards; so that, just like the equally yellow sandstones of Dornoch in Sutherlandshire and Tain in Ross-shire, they seem to form an integral part of the Old Red deposits.

2nd. The prevailing masses of the northern Oolitic and Liassic formations of Sutherland and Ross consist of numerous alternations of dark shale and deep-bluish-grey calcareous grits, with carbonaceous and ferruginous sandstones, like those of the eastern moorlands of Yorkshire, and of finely laminated, thin-bedded Liassic limestones,—the whole series being charged with shells and plants characteristic of such deposits. Not one of these strata resembles in any way the Reptiliferous sandstones and the cornstones, whether in lithological character or fossil contents.

3rd. There is, however, in the Oolitic rocks of Sutherland a peculiar band of building-stone—that of Braambury Hill, near Brora (and out of which Dunrobin Castle has been built), which, from its white colour only, might by a superficial observer be assimilated to the yellowish-white sandstones of Elgin and the coast-range of Burgh Head and Lossiemouth. But a close comparison completely dissipates this hypothesis. The rock of Braambury Hill is much more siliceous and closer-grained than the yellow sandstones of Dornoch, Tain, and Morayshire, and, unlike them, offers scarcely a trace of mica, whilst it is laden with exquisitely-preserved casts of numerous fossil shells of the Calcareous Grit or Oxford Oolite. This white building-stone is also charged with the casts of many large stems of plants of Oolitic age, whilst the underlying shale and sandstone with the *Equisetum columnare* contain thick beds of the Brora coal,—the brecciated masses of the group at Helmsdale being charged with a great variety of the plants noticed by Hugh Miller, the Duke of Argyll, and others.

It is enough, then, to say that no one of these features is to be recognized in the Reptiliferous Sandstones of Morayshire, in which neither an Oolitic shell nor a land-plant has yet been detected. These, on the contrary, are associated with cornstones and pebble-beds, and contain reptiles of genera which have never, as Professor Huxley assures me, been found in any other deposit, whether of palæozoic or mesozoic age; whilst the rocks seem to be linked on conformably to strata laden with known ichthyolites of the Old Red Sandstone.

As then it is impossible to refer these Reptile-bearing Sandstones of Elgin to a Jurassic age,—and, seeing, from their relations to the Old Red fish-beds, that it is scarcely possible to assimilate them to the Trias* or New Red Sandstone (of which there is no trace whatever on the N.E. coast of Scotland), still it might be contended that, as in many parts of the world the Devonian rocks pass up into the Lower Carboniferous, the sandstones of Elgin with Reptilian remains may be classed with the strata forming the base of the Coal-formation.

In estimating the evidences before us, it would unquestionably be wrong to dogmatize on this point, and peremptorily to separate the strata in question from the lowest Carboniferous zone. Future discoveries of other fossils may lead to such a classification, though in the present state of our knowledge no reason can be offered for the adoption of this view.

The mere fact that cornstones underlie and overlie the fish-beds, and also underlie and overlie the yellow sandstones, would seem to demonstrate that all these strata constitute one united mineral series. Although no trace of Carboniferous plants has been detected in these beds, it is to be remembered that the light-coloured sandstones of Duncansby Head, Tarbet Ness, and the Shetland Islands have afforded a rare land-plant or two, which, though apparently of genera that occur in the Coal-period, are unquestionably of very distinct species, and thus far favour the view, to which I still adhere, that these yellow sandstones (often, as before stated, of reddish colours in their northern extension in Caithness and the Orkney Islands) form really the natural upward termination of the Old Red or Devonian group—that great intermedium between the Silurian and Carboniferous systems of life.

Here, then, I close this sketch of the structure and succession of the older rocks of the North of Scotland, leaving to my associate in the Government School of Mines, Professor Huxley, the description of the reptile which is most characteristic of the youngest of the deposits under consideration on this occasion.

The only merit I claim in respect to these reptilian remains, besides the discovery, with Mr. G. Gordon, of some of their bones, is the having earnestly preferred the request to Mr. Patrick Duff to allow me to select from his choice cabinet a most curious hollow cast, which I believed to belong to a vertebrate animal, and also for having induced the gentlemen of Elgin and the neighbourhood to send up, from their instructive museum and their private stores, every remarkable fossil, the examination of which could throw light on this interesting subject.

*Note on the Fossils from near Elgin.*—The following account of the successive discoveries of the remains of Reptiles and their footsteps in Sandstones near Elgin is abstracted from a memoir recently communicated by Mr. Patrick Duff to "the Local Scientific Society of Elgin."

The first cast of scutes (scales) of the *Stagonolepis* was found in 1844, in the

* For the entire dissimilarity of the so-called New Red of the North-west Coast of the Highlands, see p. 416.

refuse of a quarry at Lossiemouth, by a labouring man named Anderson, from whom Mr. Patrick Duff obtained it. Carrying the specimen to Edinburgh, Mr. Duff submitted it to the inspection of Professor Goodsir, Dr. Rhind, Mr. Hugh Miller, Mr. Thomas Stevenson, and others, no one of whom could determine to what class of animals it belonged. After having the fossil photographed, Mr. Duff returned to Elgin, "no better informed" (as he says) "than when he set out." Then he lent the specimen to Mr. Alexander Robertson; and, that gentleman having sent drawings of it to Agassiz, the name of *Stagonolepis Robertsoni* was given to it by the great ichthyologist, as characterizing a fossil fish. The next advance was made by Capt. Brickenden in the quarry of Cummingstone, who obtained from the tacksman of the quarry a slab with a double row of footprints, figured in the 8th vol. of the Quart. Journ. Geol. Soc. Lond. Subsequently Mr. Duff and Mr. Alexander Young procured other slabs with footprints from the same quarries of Cummingstone. In 1851 the "Spynie Fossil of Elgin," afterwards named *Telerpeton* by Mantell (Quart. Journ. Geol. Soc. vol. viii.), was found by Mr. William Young at the bottom of a shaft which had been sunk through 51 feet of sandstone down to a soft rubbly bed, in which the animal had been preserved. Having obtained possession of it, Mr. Duff submitted this curious little reptile to the scientific world; and the result is known. Subsequently Mr. Alexander Young found sandstone slabs in the Findrassie Wood quarry, or on the northern slope of the Elgin ridge, marked with impressions of the scales of *Stagonolepis*; and these, with the hollow forms or moulds, in the possession of Mr. Duff, were confided to Sir Roderick Murchison's care, together with other remains in the Elgin Museum, which he requested to have sent to London, and from which Professor Huxley has procured some of his most remarkable results. Lastly, Mr. Martin, of Elgin, discovered a large bone (the bony matter being preserved) at Lossiemouth; and shortly afterwards Sir R. Murchison and Mr. G. Gordon found other bones at the same quarries; all of which have been referred by Professor Huxley to the *Stagonolepis*, some of the scutes of which (the original specimen of 1844) were found in the same spot.

Now, as these curious reptilian remains might long have remained unknown, had no liberal promoter of fossil natural history, like Mr. Duff, resided at Elgin, it is much to be regretted that neither the *Telerpeton* nor the *Stagonolepis* should have had his name attached to it as its specific distinction.—R. I. M.

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*Postscript.*—Whilst this memoir was passing through the press, the Rev. G. Gordon acquainted me with the discovery of another fossil animal in the same beds at Lossiemouth in which the *Stagonolepis* occurs, and soon after transmitted to me some of its bones. In a further search, in which he took an active part, Mr. Gordon was so fortunate as to procure many more portions of the animal in question, including vertebræ, skull, and teeth. These relics having been sent up to the Museum of Practical Geology for examination (to be afterwards returned, with other remains, to the Elgin Institution), Professor Huxley has pronounced them to belong to a Saurian reptile, about six feet long, remarkable for the flattened or slightly concave articular surfaces of the centra of its vertebræ, and for its well-developed costal system and fore and hind limbs,—but more particularly characterized by its numerous series of subcylindrical palatal teeth.

Professor Huxley terms this new reptile *Hyperodapedon Gordoni*, the specific name being given in honour of my valued friend the Rev. G. Gordon. This reptile (which, like the *Stagonolepis* and *Telerpeton*, is of a genus unknown in any other formation) will be fully described by Professor Huxley in the Monographs of the Geological Survey.

The discovery of this the third genus of Reptiles found in the uppermost sandstones of Elgin has, I confess, somewhat shaken the belief expressed in the preceding pages, that these deposits are of as remote an age as the Uppermost Old Red Sandstone. So long as the *Stagonolepis* and the little *Telerpeton* were the only evidence appealed to by palæontologists to invalidate my inference as based on the apparent stratigraphical succession and mineral character, I did not attach undue weight to them,—the more so as those animals are *generically distinct* from any fossil hitherto found.

Now, however, that Professor Huxley informs me that the *Hyperodapedon* is not only a lacertian reptile, but is closely allied to the Triassic *Rhynchosaurus*, and when I couple this determination with what he before stated, viz. that the *general* affinities of the *Stagonolepis* are also with Mesozoic reptiles, it becomes me to pause in my geological conclusions.

Throughout my researches I have invariably been mainly guided by palæontological evidence, and have never before had such a difficulty in reconciling it with the apparent succession and connexion of the strata as in the present instance. It would, indeed, have been much more in accordance with my long-cherished views, as a progressionist, to have separated the reptiliferous sandstones from the yellow ichthyolitic sandstones, really of the Old Red age, on which they rest. Not having, however, as yet been able to detect any break or physical separation between the two deposits, and believing in the passage from the red to the yellow sandstones, and even in their alternation, as shown on the banks of the Findhorn, I have naturally been strongly influenced by these physical features.

It is, however, just possible that, by a closer and longer survey, the light-coloured sandstones of Findrassie, Spynie, and the coast-ridge, with their cornstones, may be found to be of a different age from the mass of the similar yellow and whitish sandstones and cornstones of Elgin, Bishop Mill, and the Findhorn. In the endeavour to settle this question, it is my intention to revisit Morayshire during this summer, and to re-examine these tracts, with the view of laying any new evidence I may obtain on this point before the ensuing Meeting of the British Association at Aberdeen.—R. I. M., June 12, 1859.

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*Tables explanatory of the General View of the Old Red or Devonian Rocks.* (See p. 414.)

Table I.—This Table, giving a Synoptical View of the Old Red Sandstone of Britain and the Devonian Rocks of Devonshire and the Continent, with their characteristic fossils, and the List of the Fossil Fishes of the Old Red Ichthyolites of England, Scotland, and Russia, will serve to show how the terms "Old Red" and "Devonian" are synonymous.

| OLD RED SANDSTONE of Scotland, England, and Ireland. | | DEVONIAN ROCKS of Devonshire and the Continent. | | |
|---|---|---|---|---|
| 3. Upper... | Pterichthys hydrophilus, Bothriolepis favosus, Holoptychius Andersoni, H. Nobilissimus, Glyptopomus, Glyptolæmus (n. g. *Huxley*); Cyclopteris Hibernica*. | 3. Upper. *In Russia, with Old Red Fishes.* | Petherwin; Tintagel; *Boulonnais*; *Cypridinen-Schiefer* and *Clymenien-Kalk* of *Germany*. | Clymenia lævigata, C. linearis, Goniatites subsulcatus, Cardiola retrostriata, Productus subaculeatus, Spirifer disjunctus, Phacops granulatus, Cypridina serrato-striata: with plants—Lepidodendron, Calamopitys, Aporoxylon, &c. |
| 2. Middle (*Caithness Flags*) | Pterichthys oblongus, Coccosteus decipiens, Dipterus, Diplopterus, Cheirolepis Cummingiæ, Diplacanthus longispinus, Cheiracanthus, Glyptolepis leptopterus, Asterolepis Asmusii; Estheria; Coniferous trees and Lepidodendron. | 2. Middle. *Also in Russia with Old Red Fishes.* | Plymouth; Berry Head; Ogwell; Padstow; Liskeard; Combe Martin. *Nehou*; *Eifel*; *Nismes*. | Atrypa desquamata, Megalodon cucullatus, Stringocephalus Burtini, Spirifer speciosus, Sp. heteroclytus, Calceola sandalina, Cyrtoceras, Bronteus flabellifer, Cupressocrinus; Coccosteus (*Eifel*). |
| 1. Lower . | Cephalaspis Lyellii, C. Salweyi, C. Asterolepis; Pteraspis Lloydii, P. rostratus; Pterygotus Anglicus and P. problematicus, with Parka decipiens. (This zone is well represented on the S.E. flank of the Grampians—Arbroath, Dundee, &c.; but in the N.E. counties of Scotland has not yet afforded fossils.) | 1. Lower. *Wanting in Russia.* | Linton; North Foreland; Looe; Fowey; Torquay; *Coblentz*; *Normandy*; *Asturias*; *Constantinople*. | Chonetes sarcinulata, C. semiradiata, Orthis circularis, Spirifer lævicosta, Sp. speciosus, Sp. macropterus, Pleurodictyum problematicum, Homalonotus armatus, Phacops laciniatus, Tentaculites annulatus. |
| Passage-beds from Silurian to Old Red . | Onchus Murchisoni, Cephalaspis Murchisoni, C. ornatus, Pteraspis Banksii, Auchenaspis Salteri, Lingula cornea, Leperditia marginata?, Pterygotus Ludensis, and several species of Eurypterus.<br>UPPER LUDLOW ROCK.<br>Onchus Murchisoni, O. tenuistriatus, Plectrodus mirabilis, Sphagodus, Pteraspis Banksii, P. truncatus. (P. Ludensis, a new sp., occurs in both Upper and Lower Ludlow rock.) Pterygotus problematicus, P. gigas, and P. Banksii. | ........................................ | | The lower band of the Old Red Sandstone, in Russia, with *Cephalaspis Lyellii* and *Pteraspides*, is wanting,—the next overlying group being the middle or Caithness zone. |

* For the reasons assigned in the Postscript, I do not here insert the Reptilian remains (*Stagonolepis*, *Telerpeton*, and *Hyperodapedon*) in the list of fossils belonging to the Upper Old Red Sandstone. (See p. 435.)—R. I. M., June 12, 1859.

The following Table gives a connected view of the genera of fishes found in our British Old Red Sandstone, with their number and distribution in the three zones I have indicated, and may serve also for the comparison I have endeavoured to establish between the Old Red Sandstone of Scotland and England, on the one part, and the mixed Devonian formations of Russia on the other. (See p. 415.)

Table II.—*Distribution of the Species.*

| | | Lower. | Middle. | Upper. |
|---|---|---|---|---|
| *Placodermata.* | | | | |
| Pterichthys ...... | Caithness and Orkney; *Russia* ............ | ......... | 9 | 2 |
| Homothorax ?... | Dura Den ........................................ | ......... | ......... | 1 |
| Placothorax ...... | Elgin ............................................. | ......... | 1 | |
| Polyphractus ... | Caithness......................................... | ......... | 1 | |
| *Cephalaspides.* | | | | |
| Coccosteus ...... | Caithness, Cromarty, Gamrie; *Russia*...... | ......... | 6 | |
| Cephalaspis ...... | Forfarshire, Shropshire, Herefordshire ... | 4 | | |
| Pteraspis ......... | Shropshire, Herefordshire .................. | 3 | | |
| *Acanthodii.* | | | | |
| Acanthodes ...... | Elgin ............................................. | ......... | 2 ? | |
| Cheiracanthus ... | Gamrie, Stromness, Lethen Bar, Cromarty | ......... | 5 | |
| Diplacanthus ... | Caithness, Stromness, Lethen Bar, Cromarty | ......... | 6 | |
| Cheirolepis ...... | Orkney, Gamrie, Lethen ..................... | ......... | 4 | |
| *Dipterini.* | | | | |
| Osteolepis ...... | Caithness, Gamrie, Lethen Bar, &c.; *Russia* | ......... | 5 | |
| Diplopterus ...... | Caithness, Lethen Bar; *Russia*............... | ......... | 6 | |
| Glyptopomus ... | Dura Den ........................................ | ......... | ......... | 1 |
| Triplopterus ... | Orkney ........................................... | ......... | 1 | |
| *Cœlacanthi.* | | | | |
| Glyptolepis ...... | Lethen, Elgin, Gamrie; *Russia* ............ | ......... | 3 | |
| Phyllolepis ...... | Clashbinnie....................................... | ......... | ......... | 1 |
| Holoptychius ... | Elgin, Clashbinnie, Dura Den; *Eifel* and *Russia.* | ......... | ......... | 5 |
| Glyptolæmus*... | Dura Den ........................................ | ......... | ......... | 1 |
| Phaneropleuron* | Dura Den ........................................ | ......... | ......... | 1 |
| Actinolepis ...... | Findhorn; *Russia*.............................. | ......... | 1 | |
| Platygnathus ... | Orkney, Dura Den; *Russia*.................. | ......... | 2 | 1 |
| Dipterus ......... | Caithness, Lethen, Cromarty; *Russia*...... | ......... | 3 ? | |
| Dendrodus ...... | Elgin, &c.; *Russia*............................. | ......... | 4 | |
| Conchodus ...... | Scat Craig, Elgin .............................. | ......... | 1 | |
| Lamnodus ...... | Elgin; *St. Petersburg* ........................ | ......... | 3 | |
| Cricodus ......... | Elgin; *Riga* .................................... | ......... | 1 | |
| Asterolepis ...... | Elgin; *Riga, St. Petersburg*.................. | ......... | 4 | |
| Bothriolepis...... | Clashbinnie, and everywhere in upper beds; also *Russia* ......................... | ......... | 2 | 2 |
| Gyroptychius ... | Orkney ........................................... | ......... | 2 | |
| *Ichthyodorulites*—Excluded from this list as imperfect. | | | | |

* *Gen. nov.* Huxley.

TABLE III.—*Table of Fossil Fishes common to Scotland and Russia.*

Of the thirteen genera of Devonian Ichthyolites of Russia described for me by Agassiz (see 'Russia in Europe,' vol. ii. p. 397 *et seq.*), twelve are common to that country and the Scottish Old Red; whilst of the thirty species of these genera, no less than eighteen are absolutely identical with our South and North Scottish types. Now, as in Russia these Old Red fishes are found to be mixed up with species of marine shells well known in Devonshire, the synchronism of the formations in Devonshire, Russia, and Scotland is established.

Pterichthys major, *Ag.* Elgin; Findhorn;—Riga; Andoma.
Bothriolepis (Glyptosteus) favosa, *Ag.* Clashbinnie; Elgin;—Russia (common).
—— (G.) ornata, *Ag.* Monachty; Nairn;—Russia.
Osteolepis major, *Ag.* Lethen;—S. of Petersburg and Kokenhusen.
Diplopterus macrocephalus, *Ag.* Lethen;—S. of St. Petersburg; Priutchka.
Glyptolepis leptopterus, *Ag.* Lethen; Caithness; Dipple;—S. of St. Petersburg.
Holoptychius nobilissimus, *Ag.* Clashbinnie; Elgin;—Priutchka.
—— Andersoni, *Ag.* Dura Den;—S. of St. Petersburg.
Actinolepis tuberculatus, *Ag.* Findhorn;—S. of St. Petersburg.
Platygnathus Jamesoni, *Ag.* Dura Den;—S. of St. Petersburg.
Dendrodus latus, *Owen.* Findhorn;—Riga.
—— strigatus, *Owen.* Scat Craig, Elgin;—Riga; S. of St. Petersburg.
—— sigmoides, *Owen.* Scat Craig, Elgin;—S. of St. Petersburg.
Lamnodus biporcatus, *Ag.* Elgin;—Riga; S. of St. Petersburg.
—— Panderi, *Ag.* Elgin;—Riga; S. of St. Petersburg.
Cricodus incurvus, *Ag.* Elgin;—Riga.
Asterolepis Asmusii, *Ag.* Elgin; Caithness; Orkney;—Dörpat; Riga.
—— minor, *Ag.* Elgin;—Riga; S. of St. Petersburg.

In Russia, beds containing the above-mentioned fossil fishes overlap both Lower and Upper Silurian, including in the latter the equivalent of the Ludlow Rock. As the mass of the Lower Old Red is wanting, there is nowhere in Russia a complete transition from the Upper Silurian into the Old Red, as in Shropshire and Herefordshire. In that typical Silurian tract of Britain, the geologist observes a gradual passage from the Bone-bed and Downton Sandstone with a few Ludlow fishes, through certain intermediate beds* into the base of the Old Red with *Cephalaspis.*

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* I will not venture to say that some of the beds called by Pander Upper Silurian (and which contain fishes closely allied to, if not identical with, *Cephalaspis*, *Auchenaspis*, or *Pteraspis*) may not be the equivalents of the passage-beds above noticed.

## 2. *On the* STAGONOLEPIS ROBERTSONI (Agassiz) *of the* ELGIN SANDSTONES; *and on the recently discovered* FOOTMARKS *in the* SANDSTONES *of* CUMMINGSTONE. By THOMAS H. HUXLEY, F.R.S., F.G.S., Professor of Natural History, Government School of Mines.

(PLATE XIV.)

CONTENTS.



*Introduction.*—In establishing the genus *Stagonolepis* Prof. Agassiz remarks *—"I have founded this genus upon a slab on which the impression of many series of great rhomboidal scales, arranged in the same way as those of the *Lepidosteidæ*, is observable. The angular form of these impressions allows of no doubt that the fish whence they proceeded was a great ganoid similar to *Megalichthys*. The absence of the fins, of the head, and of the teeth, however, renders the exact determination of the family to which the fossil belongs impossible. I arrange it provisionally in the neighbourhood of the genus *Glyptopomus*, to which it presents some analogy in the ornamentation of its scales."

Prof. Agassiz goes on to say, in a subsequent paragraph, that the fossil came from the Upper Old Red at Lossiemouth; that he had not himself seen the original, and that he was acquainted with it only through Mr. Robertson's drawings.

*Stagonolepis* has remained ranged among the fishes in all the works on Geology and Palæontology which have been published since the appearance of the 'Monographie.' Sir C. Lyell, however, informs me that some years ago, after perusing the memoir on *Mystriosaurus* by Dr. A. Wagner, to which I shall have occasion to refer by and by, his suspicions were roused as to the real affinities of this so-called fish; and he even communicated to the late Mr. Hugh Miller his doubts (based on the strong resemblance which he perceived between the sculpture of the dermal plates of *Stagonolepis* and that represented by Dr. Wagner in the scutes of *Mystriosaurus*) whether, after all, *Stagonolepis* might not be a reptile. That eminent investigator of the Old Red Sandstone fossils was, however, so fully satisfied of the piscine nature of the remains that Sir Charles Lyell did not press his objections, and it might have been long before the question had been revived had not Sir Roderick Murchison been led to visit the Elgin country in the course of the present year (1858). On examining the bony remains associated with scutes of *Stagonolepis*, some of which were preserved in the Elgin Museum and in the collections of Mr. Patrick Duff and of the Rev. Mr. Gordon, while others were collected by himself, Sir R. I. Murchison was so impressed by their obviously reptilian characters that he

* Monographie des Poissons fossiles du vieux grès rouge, p. 139.

used every exertion to gather together all the evidence which could tend to elucidate so important a question. In pursuing this object, Sir Roderick was aided in the most zealous and liberal manner by the Committee of Management of the Elgin Museum, by Mr. Patrick Duff, and by the very active personal exertions in the field of the Rev. George Gordon.

To the two latter gentlemen my own thanks are also especially due for their prompt courtesy in attending to the many inquiries and requests with which I have had to trouble them, since it became my duty, in accordance with the instructions of the Director-General of the Geological Survey, to enter upon the investigation of these remains.

Thanks to these many helping hands and heads, that duty has been rendered far easier of performance than it promised at first to be, and I hope to exhibit to the Society to-night such an amount of evidence as will fully justify the conclusions I have to propound.

I would premise that, on the present occasion, I purpose to speak only of such portions of the ancient reptile—for such it truly is—as bear directly on those conclusions; and that the full description and illustration of all the remains which have been discovered will be reserved for the Memoirs of the Survey *.

The reptilian fossils from Elgin, which have passed though my hands, are of three kinds:—1st, Bones; 2nd, Natural casts of bones and teeth; 3rd, Footprints.

Of these, the first have been derived exclusively from the Lossiemouth quarries; the second are almost wholly from Findrassie; while the third class of remains is derived exclusively from Cummingstone. I am informed that up to the present time † no fossils referable to vertebrate animals have been found in either of these localities, save such as may with the highest probability be considered to belong to *Stagonolepis*.

*Dermal Scutes of Stagonolepis* (Pl. XIV. figs. 1, 2, 3).—The first series of remains of which I purpose to speak are the dermal scutes and their casts.

Of these there are two kinds: the one distinguished by their flattened outer and inner surfaces and nearly square shape; the other, by having a bent or angulated contour arising from the possession of a longitudinal ridge externally, and of a correspondingly excavated inner surface. While the former, which, for distinction's sake, may be termed the *flat scutes*, preserve pretty nearly the same dimensions, the latter, or *angulated scutes*, vary greatly in size, some being very much larger, and others as small as, or even smaller than, the flat scutes.

The characteristic features of the *flat scutes* are best exhibited by the specimen upon which the genus was originally founded. It is

* In order to render the following pages as useful as possible to the ordinary readers of the Journal, I have given a disproportionately full description, accompanied with figures, of the scutes and footmarks, as it is in these parts that the pure geologist is most likely to be interested.

† See the concluding Note to this paper, p. 459.

very briefly described by Prof. Agassiz, and is figured in pl. 31, figs. 13 and 14, of his already cited 'Monographie.' The specimen is an irregularly broken mass of sandstone, exhibiting numerous impressions of four-sided scutes, of which there are altogether five rows in one direction and eleven in the other. A plaster-cast (Pl. XIV. fig. 1) shows, even better than the original, that, while one opposed pair, out of the four edges of each scute, fitted against the adjoining edges of the scutes on each side, the other pair of edges alternately overlapped, and were overlapped by, those of the adjacent scutes. There can be no doubt that the overlapped edges were anterior, and, as I shall presently show that these scutes formed part of the ventral armour of the animal to which they belonged, the direction and relations of each row become at once definable. The five rows are longitudinal—the eleven transverse. None of these rows are complete. The left-hand longitudinal row contains five scutes, whose outer (left) edges are more or less broken away. The next row contains seven scutes, the posterior of which are somewhat thrust forward, and their left edges somewhat broken. The third row contains eight scutes. Each of these longitudinal rows extends to the same level anteriorly; but the next, or fourth, series begins opposite the fifth scute of the third series, and but a very small portion of its first scute is visible. It contains six scutes, of which the hindermost are somewhat displaced and thrown forwards one upon the other. The fifth series contains only portions of five scutes, which are more or less displaced towards the right side*.

An additional small fragment of a scute is visible in front of the first and third series. Each scute is on exactly the same level as its right-hand and left-hand neighbour, so that the structure of the whole fragment is extremely regular.

About a fifth of the outer surface of each scute is covered by the posterior edge of its predecessor; and the fifth and sixth scutes of the fourth series are sufficiently displaced to show that the covered surface was smooth and bevelled off obliquely, so as to constitute a sort of articular facet, narrow and parallel-sided antero-posteriorly, but very wide transversely.

The posterior edge of this facet is cut perpendicularly to the plane of the scute, from whose face it rises like a kind of parapet. The face of the scute is ornamented with a peculiar sculpture, consisting of distinct deep pits. The casts of these are of course elevated, and lie like drops upon the general surface of the impression—an appearance which doubtless suggested the name of the genus. Near the centre of the face of the scute the pits are nearly circular in outline, but towards the periphery they elongate in the direction of radii from a point rather nearer the anterior than the posterior edge of the whole scute, and assume a pyriform shape, the small end of each being directed inwards. The consequence of this arrangement is a very marked radiation of the ornamentation from

* I have applied the terms right and left here, not to the true right and left series of scutes, but to those which appear to be right and left when the face of the fossil is turned towards the observer and its anterior end is forward.

a centre which lies about the junction of the anterior two-fifths with the posterior three-fifths of the whole ornamented surface. A small marginal space, laterally and posteriorly, is, as Prof. Agassiz has observed, free from sculpture (fig. 1).

An inch and a quarter transversely, by a little less antero-posteriorly, is a fair statement of the average dimensions of these flat scutes, of which I have only seen one or two detached impressions among the more recently discovered remains of *Stagonolepis.*

The *angulated scutes* may be roughly divided into three kinds: the *broad,* the *thick,* and the *irregular.*

The *broad angulated scutes* (fig. 2) have a transversely elongated trapezoidal form,—one of the short sides, which it will appear is the outer, not being parallel to the other, but sloping obliquely outwards and forwards. The largest of these scutes which I have seen is a well-preserved specimen from Lossiemouth, which, with the exception of a very small portion of its anterior and inner edge, is entire*. The anterior edge has a length of $4\frac{7}{8}$ inches; the posterior of $4\frac{3}{8}$ inches. The length of the scute in the middle line is $2\frac{1}{2}$ inches. The inner edge is straight; the outer, somewhat convex behind and concave in front, passes into the produced antero-external angle. The inner surface only of this scute was visible, but, by cutting away a portion of its substance, the ornamentation of the outer surface and its natural cast in the sandstone came into view, so that the relations of both surfaces could be observed. The contour of the outer surface is somewhat concave from before backwards, and the anterior edge of the scute is bevelled as in the flat scutes; the articular facet (*a*) thus formed is wider externally and internally than in the middle.

About $1\frac{5}{8}$ inch from the inner edge, and therefore much nearer the inner than the outer, a strong longitudinal ridge appears upon the scute, and, rising posteriorly, ends upon the hinder edge of the bony plate in a sort of rudimentary spine (*b*), while anteriorly it gradually dies away. The outer face of the scute falls away rapidly on each side from the ridge, so that, while measured through the ridge, the posterior margin of the scute is $\frac{7}{16}$ths of an inch thick, at a distance of three-quarters of an inch from it, on the outer side, it measures hardly more than $\frac{1}{8}$th of an inch, and is but little thicker at a like distance on the inner side.

The outer surface of this *wide angulated* scute is sculptured in the same way as that of the flat scutes, but the pits are larger, and the marginal ones are so much elongated as almost to deserve the appellation of grooves. The posterior, most prominent part of the ridge, is devoid of sculpture. The inner surface of this and of other scutes of the same order is quite smooth, except posteriorly, where it presents a fine transverse striation; and its contour is totally different from that of the outer surface. Transversely it is concave, each side sloping towards a longitudinal valley, which corresponds with the

* I have since seen a specimen of one of these scutes $5\frac{1}{2}$ inches wide by $2\frac{1}{2}$ inches long.—July 5th, 1859.

external ridge, and therefore lies altogether on the inner side of the middle line. The transverse concavity is least in the middle of the scute and greatest at its posterior edge.

Antero-posteriorly the inner surface is very convex in the middle line, its anterior and posterior moieties meeting in a rounded transverse ridge, which is nearer the anterior than the posterior margin. That part of the scute which lies behind this transverse boundary is much thicker than that which lies in front of it. None of the numerous wide angulated scutes which I have met with have been less than two inches in transverse diameter.

Of the *thick angulated scutes* to which I have referred, I know only the inner faces, and the minimum thickness, as no one of the specimens (which are all natural casts) shows the outer face. Again, the only specimens I have met with have been associated with remains belonging to the anterior part of the body, such as the scapulæ or the ribs.

A cast of one of these, on the same slab with the impressions of two scapulæ, is two inches long in the middle, and has the same width at its widest part, but it is not quite square. The side which I take to be the inner is nearly straight; and the inner edge, which is $2\frac{1}{6}$ inches long, appears to have been thick, and serrated for sutural union with its fellow. The anterior side measures about $1\frac{3}{4}$ inch in length, and is somewhat broken, so that its proper contour can hardly be made out. The junctions of the internal anterior and posterior edges appear to have been sharply angular, while the antero-external angle was slightly, and the postero-external angle greatly, rounded off. The internal surface is convex from before backwards, concave from side to side.

I have found scutes very similar to these, but smaller, associated with the impressions of some ribs. The smallest of these was not more than an inch long, and one which had a length of $1\frac{1}{2}$ inch was fully half an inch thick at its postero-external angle. On the other hand, scutes of this kind appear in some cases to have attained a width of more than four inches, and a thickness of seven-eighths of an inch.

The *irregular angulated scutes* (fig. 3) are pentagonal or rhomboidal, the ridge by which they are marked externally projecting so far backwards that their posterior margin (*b*) becomes triangular. One of the largest of these had a length of $1\frac{7}{8}$ inch by a breadth of half an inch, and had a roughly pentagonal form, its anterior edge being slightly convex. Another had a length of $1\frac{1}{2}$ inch by a breadth of $\frac{5}{8}$ths of an inch, and presented only a very small sculptured surface close to its anterior margin. In fact, the proportion of the sculptured to the smooth surface was far less in these than in the wide scutes.

I have compared the parts which have just been described with the scales of *Glyptopomus*; and, though there is a certain resemblance between the latter and the flat scutes, the dermal plates of no fish with which I am acquainted present any similarity to the angulated and thick scutes. On the other hand, any one acquainted with the characters of the exoskeleton in the Crocodilian Reptiles can hardly fail to have his attention arrested by the remarkably similar features of the scutes of *Stagonolepis*; and close investigation shows that there is not a single peculiarity of the latter which may not at once be paralleled by those of Crocodilian scutes. To begin with the sculpture or ornamentation,—the outer surface of the scutes exhibits distinct rounded pits, so disposed as to appear to radiate more or less distinctly from a common centre, not only in the modern Crocodiles, but in the Eocene *Crocodilus Hastingsiæ* and in the Mesozoic *Teleosauria*. Wherever these scutes possess a median ridge, the centre of radiation of the pits is somewhere on that ridge, and the highest part of the ridge is devoid of sculpture. Next, in respect of their form—the variously-shaped scutes of *Stagonolepis* become readily intelligible when those of the existing and extinct *Crocodilia* are understood. To this end, however, I must here interpolate a brief disquisition upon the characters of the dermal armour in the *Crocodilia* in general,—a subject upon which I have not found it very easy to gain definite information.

*Dermal Scutes of Recent Crocodilia.*—So far as my present information goes, there are two modes of arrangement of the dermal armour among the *Crocodilia*—the one characteristic of the recent Crocodiles, the other known to exist in the Amphicœlian genera. In the recent *Crocodilia* there are numerous longitudinal series of dermal plates upon the dorsal region of the body. The large and regular scutes are divisible into three distinct sets: nuchal, cervical, and dorso-caudal. The scutes do not always overlap, and in the dorsal region there may be as many as ten regular and large scutes in a transverse row. Along the margins of the shield formed by the regular scutes small and irregular ones are scattered.

The ventral armour varies greatly, no osseous plates at all being developed in this region in some recent *Crocodilia*, while in others I find the ventral shield to be very largely developed.

In the Amphicœlian *Crocodilia**, at any rate in the *Teleosauria*, the disposition of the dermal armour, as will be shown below, is very different. The most numerous scutes are on the ventral surface of the thorax and abdomen, where they form six longitudinal, and as many as twenty transverse rows. In the dorsal region, on the other hand, no distinct nuchal and cervical scutes have as yet been discovered; and in the dorso-caudal regions, the scutes, which are occasionally very large, and are usually broad in proportion to their length, never form more than two longitudinal rows, the scutes of each row being suturally united in the middle line, and free at their outer edges. There is no evidence of the existence of any scattered

* The scutes of the specimen of *Goniopholis crassidens* in the British Museum exhibit a narrow smooth articular facet along that edge which is produced into the peg; but I am not aware that there is any evidence to show whether these scutes were dorsal or ventral, or in what manner they were arranged. Their sculpture consists of distinct pits; but the peripheral pits are not particularly elongated, and hence there is no marked appearance of a radial arrangement.

small scutes, or that anything but soft parts united the dorsal with the ventral shield.

Such are the chief modes in which the dermal armour of the *Crocodilia* is disposed. With respect to the form and mode of union of the component scutes, it does not appear that many general rules can be laid down. The scutes are, however, always disposed symmetrically with regard to the median planes of the back and belly, in such a manner that the middle line answers to the interval or suture between two longitudinal rows of scutes*.

The dorsal scutes almost always present a more or less marked longitudinal ridge externally, while the ventral scutes, when they exist, have either flat and smooth, or evenly curved, external surfaces.

In some procœlian recent *Crocodilia*, such as *Crocodilus acutus*, there are no ventral osseous scutes. The dorsal scutes, on the other hand, are well developed; they are either square, pentagonal, or hexagonal, and their lateral edges are very irregular and jagged. I cannot find in any case, however, that they interlock so as to unite suturally,—a greater or less portion of the dermis being in all cases interposed between their edges. The scutes nowhere overlap, and, as might be expected, they exhibit no articular facets.

Each scute presents externally a strong longitudinal ridge, which lies on the outer side of the median line, and cuts the hinder margin of the scute posteriorly, while anteriorly it subsides into the general surface at some distance from the anterior margin. The highest point of the ridge is far nearer the posterior than the anterior margin.

The inner faces of the scutes are smooth, concave from side to side, and slightly convex from before backwards.

Scattered about between the ventral and cervical, and the cervical and dorsal shields, there are many small and irregular detached scutes, of all sizes down to $\frac{1}{8}$ths of an inch in length. The smallest of them are simply incipient ossifications in the dermis which underlies the ridges of the epidermic scales, and they present no sculpture. In fact they correspond with the apices of the ridges of the larger scutes. In some of larger size, which present a certain amount of sculpture, the apex of the ridge is altogether posterior, and the scutes very closely resemble the smaller *irregular angulated* scutes of *Stagonolepis*.

Other existing procœlian *Crocodilia* present a far more complete dermal armour; and certain Alligators, of the genus or subgenus *Jacare*†, are not surpassed, so far as I am aware, by any recent

* The only exceptions to this rule that I am acquainted with are offered by the scutes of the median caudal crest, and by a small extent of the dorsal region of the tail, just in front of the point of convergence of the lateral crests. Here there is a variable number of scutes, which lie one behind the other, gradually diminishing in size, in single series, so that their centres correspond with the median line.

† *Alligator lucius*, like *Crocodilus vulgaris*, has no ossified ventral scutes. *Caiman palpebrosus* has ventral scutes like those of *Jacare*, of which I have

*Crocodilia*, and certainly not by any of the fossil members of the group; though Cuvier calls *Teleosaurus Cadomensis* "le mieux cuirassé" of the group to which it belongs. I shall describe the dermal skeleton of the *Jacare* at length in another place; but I may remark here, that the broadest part of the dorsal shield exhibits eight or ten scutes in each transverse row, and that all the dorsal scutes overlap their successors by their posterior edges, and are united to one another by strong serrated sutures. The ventral shield consists, in its broadest part, of 12–14 scutes in a transverse row. Each scute, except the two outermost of the series, has four straight sides, the anterior of which presents a large, smooth, articular facet, while the posterior overlaps the facet in its successor. The lateral edges unite in firm serrated sutures. The outer faces of these scutes are quite flat, and their ornamentation is so very similar to that of the *Stagonolepis*, that it would require very close attention to distinguish a cast of the one from a cast of the other. Multitudes of small, irregular, posteriorly pointed, osseous scutes cover the skin of the sides of the body, and extend on to the limbs.

*Dermal Scutes of Fossil Crocodilia and Teleosauria.*—Among the fossil procœlian *Crocodilia*, the scutes of *Crocodilus Hastingsiæ* are provided with articular facets, and I am inclined to think that this Crocodile also had a ventral shield.

With regard to the Amphicœlian Crocodiles, the broad statement I have made above must be held at present to apply only to the *Teleosauria*, and naturalists in general do not seem to have admitted its truth even for them. Cuvier, for instance, remarks, with regard to his "Crocodile de Caen" (*Teleosaurus Cadomensis*, Geoffroy), "They are rectangular and very thick, but are thinned towards their edges, and the whole of their external surface is excavated by little, close-set, hemispherical fossæ, of the size of a lentil or that of a pea..... These scales were disposed, as in our living Crocodiles, in regular series, longitudinally as well as transversely. The posterior edge of the one covered the base of that which followed it. The block belonging to the Caen Academy presents almost all the scales of one side in their natural position. It is seen that, from the first of the dorsal vertebræ which have been preserved to the origin of the tail, there are 15 or 16 transverse series, and that each series had five scutes on each side, so that there were at least ten longitudinal series *."

The "Grand bloc de l'Académie de Caen," here referred to, is figured in Cuvier's plate 235, fig. 14. The scutes represented are all flat, four-sided, and nearly square, and their internal surfaces only are represented. Moreover, the figure clearly shows six longitudinal rows, and not five. I have no doubt that the scutes figured did in fact form a part of the ventral armour, and not, as Cuvier supposed, of the dorsal shield. I am the more inclined to adopt this opinion because Geoffroy St.-Hilaire, to whom we are indebted for the

examined two species, *J. fissipes* and *J. sclerops*. I have nowhere been able to find the slightest allusion to the existence of this singularly developed ventral armour in modern *Crocodilia*. (See concluding Note, p. 459.)

* Ossemens Fossiles, vol. v. part 2, pp. 139, 140.

first accurate description of the dermal skeleton of the Teleosaurians, and who had the opportunity of examining all the specimens described by Cuvier, writes thus, without referring to Cuvier's statement:—

"In the Teleosaurians it is the ventral plastron which is the more complete. It is protected by numerous contiguous series of six strong thick scales, which are flat and imbricated at their posterior edges. Upon the back there are indeed other larger scales, but they are only two in number in each row; bent scales exist only on the upper part of the tail *."

*Dorsal Scutes.*—As the Tesson Collection has recently been purchased for the British Museum, some of the specimens on which Geoffroy made his observations are probably to be seen there. At any rate, the beautifully preserved remains of *Teleosaurus temporalis* and *T. Cadomensis*, in that collection, fully bear out his statements. In these *Crocodilia* (and I may add in *T. Bollensis* in the same collection), the dorsal scutes are arranged in only two longitudinal series, or, in other words, there are only two scutes in the successive transverse rows, which occupy the middle of the dorsal region. In *T. Cadomensis*, it is clear that each pair of scutes corresponds with a vertebra; and the posterior two-thirds of the broad terminal face of the short and thick spinous process is so shaped that the interior faces of its appropriate pair of scutes seem to have rested upon and have been closely connected with it. The internal edge of every scute is thick, and interlocks with its fellow by strong serrations. The suture thus formed lies in the middle line. The anterior edge presents a broad articular facet, overlapped by the posterior edge of the preceding scute; the posterior edge thins out to overlap its successor. The outer edge also thins out, and neither its upper nor its under surfaces present the least trace of overlapping, or being overlapped by, or articulating with, other scutes.

Dr. A. Wagner †, who has given a very good account of the dermal armour of *Teleosaurus Cadomensis*, finds only two longitudinal rows of dorsal scutes, either in this species or in *Mystriosaurus Muensteri*. Bronn and Kaup‡ figure only two longitudinal series of dorsal scutes, in their *Pelagosaurus typus*; and I can nowhere find the least evidence that the dorsal scutes were connected by anything more than the general integument with the lateral or ventral scutes.

Prof. Owen § admits the existence of a double row of large or peculiarly formed medio-dorsal scutes in *Teleosaurus Chapmanni*; but he evidently conceives, from the following passage, that the lateral scutes were directly articulated with the dorsal ones, so that the body was surrounded by continuous circles of bony plates:—

* Mémoires de l'Académie, vol. xii. p. 24.

† Abhandlungen über die Gavial-artigen Reptilien der Lias-Formation, 1842.

‡ Die fossilen Ueberreste Gavial-artigen Saurier aus der Lias-Formation in der k. paläontologischen Sammlung zu München. Abhandlungen der Mathem.-Physikalischen Classe der Königlichen Bayerischen Akademie der Wissenschaften, Bd. v. 1850.

§ Report on British Fossil Reptiles, Rep. British Assoc. 1841.

"The verticillate cuirass of these ancient Crocodiles is thus securely braced round the trunk by this interlocking of the inferior extremities of each ring of scutes, whilst the imbricated arrangement would allow of a certain sliding motion of the rings upon each other, sufficient for the expansion of the chest in breathing."

No evidence is produced in favour of the existence of a structure so aberrant from that of the other Teleosaurians, and it seems to me that, in leaving an interspace between the dorsal and ventral shields, nature has provided for the wants of the economy in a far more efficient manner than that here imagined.

*Ventral Scutes.*—The characters of the ventral armour of the *Teleosauria* are beautifully displayed in the two specimens from the Tesson Collection, of *Teleosaurus temporalis* and of *T. Cadomensis,* to which I have referred. The ventral shield is, in the latter case, incomplete; but the scutes are imbedded undisturbed in the rock. In the *Teleosaurus temporalis,* on the other hand, the shield is nearly complete, but all the parts have been artificially fitted together upon a plaster-slab; by whose hand I know not. The comparison of the two specimens, however, leads me to believe that the operation has been very carefully and conscientiously effected.

In *Teleosaurus temporalis* the scutes are so arranged that the middle line is occupied by the suture between the two innermost rows, and that there are three longitudinal rows on each side. Anteriorly, the innermost scutes are nearly square, while posteriorly they become pentagonal, or even hexagonal. The scutes of the two outer rows on each side are also nearly square anteriorly, but more or less completely hexagonal in the posterior part of the shield; and, from the manner in which the scutes are fitted together, the result is, that, while the anterior transverse rows are nearly or quite straight, the posterior ones form an angle, open forwards on each side of the middle line, so that each of the hinder rows assumes somewhat the form of a W.

There are altogether twenty transverse rows of scutes. Those of the last row do not exist in the specimen, but, from the outlines on the plaster, were evidently thought by its restorer to be smaller than those which preceded them, and to be so arranged as to give a rounded posterior margin to the ventral shield. Anteriorly, also, the scutes are partially wanting; but the transverse rows appear at first to have had not more than half their greatest width, and the anterior five rows seem to have contained only two scutes on each side of the median line. The shield does not attain its full width before the tenth series.

The lateral edges of the scutes are united by serrated sutural edges. The anterior edge of each exhibits a bevelled articular facet, occupying nearly a third of the whole external surface, and overlapped by a corresponding extent of the posterior margin of the preceding scute. Both surfaces of these scutes are smooth and flat, and the pitted sculpture radiates from a point which nearly corresponds with the centre of each scute, in a fine specimen of a fragment of the ventral shield of *Teleosaurus Cadomensis* (32,591 B.M.). The external scutes on each side are somewhat bent up towards the dorsal surface; but in this, as in other specimens, the outer margins of these scutes thin out, and exhibit not the least sign of having been connected with any other. In this respect there is a marked contrast between the outer and the inner edges.

There are six longitudinal rows in this specimen, which is the number assigned by Geoffroy St.-Hilaire (*supra*, p. 448) to the *Teleosauria* generally. Six exist, as we have seen, in *T. temporalis*. Dr. Wagner found only five in his specimens of the ventral shield of *T. Cadomensis*; but, as he states, it was imperfect. Six are, as I have pointed out, represented by Cuvier in *T. Cadomensis*, and the same number is shown in the figure, given by Bronn and Kaup, of *Pelagosaurus typus*. These authors state that there are ten longitudinal rows of scutes in the dermal armour of *Mystriosaurus longipes*; but their figures and description make me think that this is a hypothetical conclusion, and that what they have seen and figured is only the ventral armour, with its six rows of plates.

I cannot ascertain from Prof. Owen's description what is the precise number of longitudinal series of "lateral and ventral" scutes in *Teleosaurus Chapmanni*. They are said to be "more perfect squares than those next the spine," and to have no keels. In these respects they obviously agree with the corresponding scutes of the *Teleosauria*; but it is stated that "the median abdominal scutes are not opposite but alternate; their median margins are rounded off or slightly angular; and, while the anterior part of that margin is overlapped by the posterior half of the opposite scute in advance, the posterior half overlaps the succeeding scutum of the opposite side." This description would apply much better to the sutures between a median series and that which follows it externally, than to the junction between the two median series of scutes, which are always opposite in the *Teleosauria* I have examined.

The internal faces of the dorsal scutes of the *Teleosauria* are concave from side to side, and convex from before backwards; they may be smooth or carinated, but the ventral scutes appear to be always flat and without a keel.

*Comparison of the Scutes of Stagonolepis with those of Crocodilia and Teleosauria.*—Bearing in mind the features of the dermal armour of the *Crocodilia* which have just been detailed, it becomes no difficult matter at once to find an analogue for each kind of scute found in *Stagonolepis*. The *flat scutes* are strictly comparable to those of the ventral shield of the *Teleosauria*, the *broad* and the *thick angulated scutes* to the dorsal scutes of the same Crocodilians, while the *irregular angulated scutes* are very similar to the dermal bones, which are scattered between the margins of the dorsal and cervical shields of the existing Crocodiles.

At this stage of the inquiry, the full meaning of a piece of evidence, whose value I had, up till then, but very imperfectly recognized, became obvious. This was a remarkable natural cast, obtained by Mr. Patrick Duff, at Findrassie, and which had been sawn through longitudinally by that gentleman's direction, so as to expose its internal conformation. At first sight this curious fossil resembled nothing so much as the crushed and distorted cast of an *Orthoceras*, but both Mr. Duff and Sir Roderick Murchison had suspicions of its real nature, and in fact it turns out to be one of the most singular organic remains ever discovered, consisting of a natural cast of both the dermal bones and the vertebræ of a considerable segment of the tail.

Loaded by its heavy dermal plates, this caudal fragment appears to have sunk into the fine siliceous mud, the accumulation of which has given rise to the Findrassie sandstone, and to have been completely permeated therewith, all the cavities left vacant by the putrefaction of the soft parts becoming filled up with a substance which soon hardened into stone. After this had taken place, the bony matter was, by some agency or other (probably the percolation of water), completely removed, so that the fossil, which must have originally lain loose in a natural mould of the outer surfaces of the caudal scutes (which has unfortunately not been preserved), exhibits, externally, a complete cast of the inner surfaces of a number of successive transverse series of scutes, and, internally, the casts of the outer surfaces and neural canals of a corresponding number of caudal vertebræ.

The impressions of the dorsal scutes are but little disturbed, and it is at once obvious that they belonged to the kind which I have named above *broad angulated scutes*. They form a double series along the dorsal region of the tail, and their inner edges meet along a median sutural line.

The ventral scutes also appear to have formed only a double series, meeting in the middle line; but they are much more displaced, the left-hand set being particularly thrown out of position. These scutes are nearly square, and perfectly flat, corresponding exactly in form with the *flat scutes* already described. It would appear that in the caudal region (as was probably the case in the *Teleosauria*) the outer margins of the dorsal and ventral shields came into close contact.

By the discovery of the true nature of this fragment, the conclusions to which the structural characters of the different kinds of scutes pointed were completely verified, and I had thenceforward no hesitation in assuming that *Stagonolepis* was provided with a dorsal and a ventral dermal shield, composed of scutes resembling those of *Jacare, Caiman, Crocodilus Hastingsiæ*, and the *Teleosauria*, in the manner in which their anterior and posterior margins are articulated together.

With respect to the mode in which the scutes were arranged to form the ventral and dorsal shields, *Stagonolepis* would appear to have resembled the *Teleosauria*. The fragment of the ventral shield which I described first is extremely like a portion of the anterior region of the ventral shield of a *Teleosaurus*, and it will be observed that it only contains five longitudinal rows of scutes.

On the other hand, all the impressions of the *broad* and *thick angulated scutes* which I have met with have one lateral margin straight, and apparently fitted for sutural union with the corresponding margin of another scute, while the other margin is rounded off, and is either thin, or, if thick, shelves off rapidly to a thin edge. Hence I conclude that these dorsal scutes formed, as in the *Teleosauria*, only a double series, and that their external edges were not, except perhaps in the caudal region, connected with other scutes.

The *irregular angulated scutes* only remain to be accounted for. They have much resemblance to the small scutes which are scattered along the margins of the great dorsal shield of existing Crocodiles; but it is possible they may have belonged to the narrower part of the tail.

To sum up in a few words the results of this long inquiry, it is evident that, in its dermal armour, *Stagonolepis* is altogether a Crocodilian Reptile.

*Bones of the Stagonolepis.*—I will abstain, at present, from particularly describing the impressions of ribs, of two scapulæ, and of the posterior face of the second sacral vertebra of *Stagonolepis*, because all these parts nearly resemble the corresponding bones of ordinary *Crocodilia*. Had my acquaintance with the organization of the Elgin reptile been confined to the remains already mentioned, in fact, I should have been fully justified, according to the ordinarily accepted canons of paleontological interpretation, in prophesying that any other parts which should be brought to light would conform very closely to the Crocodilian, and especially the Teleosaurian, type. It was a useful warning, however, to find that I should have been unsupported by the event, had I done so; for all the other remains depart, more or less widely, from the ordinary Crocodilian type of organization. The smallest amount of difference is perceptible in the femur, an incomplete cast of part of the shaft and distal end of which bone (of the left side) shows that it was thicker and stouter in proportion than that of the Crocodile. The impressions of the articular surfaces of the condyles, again, are so rough and irregular as to lead to the suspicion that they were covered by imperfectly anchylosed epiphyses—which is the reverse of a Crocodilian character.

The cast of the only example of a metacarpal or metatarsal bone which has come to light also exhibits proportions which indicate a much shorter and thicker foot than the corresponding bone in the modern Crocodiles, and, *à fortiori*, than in the *Teleosauria*. The proportions of these bones, then, lead us to look for a stouter thigh and a shorter and broader foot than exist in the *Crocodilia*. On the other hand, the single natural cast of a long and nearly straight bone, which I can only regard as an ungual phalanx, indicates a length of claw wholly foreign to the Crocodilian foot.

The vertebræ, whose more or less perfect natural casts have passed through my hands, all belong either to the dorsal, the sacral, or the caudal series. The impression of part of a sacral vertebra, to which I have already alluded, shows that in this region the structure of *Stagonolepis* was very similar to that of known *Crocodilia*; but the dorsal and caudal vertebræ are remarkable, partly for the lateral constriction and inferior excavation of their centra, partly for the obliquity of the planes of their slightly concave anterior and posterior articular faces. These faces, in fact, are not perpendicular to the longitudinal axis of the centrum, but the anterior one looks a little downwards and forwards, the posterior, upwards and backwards.

The neural arches were readily detached from their centra, and, where a separation has taken place, the previously co-adapted surfaces of the centrum and the arch exhibit strong ridges and grooves, which mutually interlocked. The edges of the posterior zygapophyses meet inferiorly above the neural canal (which is deepest in the middle), forming a kind of inverted V.

These and some other peculiarities of the vertebræ of *Stagonolepis* are all shared by the *Teleosauria*, and may be readily seen in many of the detached Teleosaurian vertebræ in the British Museum; but the vertebræ of the reptile under description present two remarkable characters, for which I can find no exact parallel in either recent or fossil *Crocodilia*.

The first of these is exhibited by each of two imperfect natural casts of anterior dorsal vertebræ, the strong and broad transverse processes of these vertebræ being bent upwards and backwards at an angle of 45° to a horizontal or vertical plane. The second peculiarity is exhibited by the caudal vertebræ, whose transverse processes come off altogether above the neuro-central suture, whereas ordinarily they are, as it were, wedged into this suture, and separate the centrum more or less completely from its neural arch.

With regard to the first of the special characters here noted, it may be observed that the anterior dorsal vertebræ of different species of modern *Crocodilia* vary a good deal in the extent to which they incline upwards and backwards, and those of some *Enaliosauria* suffer a still more marked deflexion in the same direction; but it is among the Dinosaurian reptiles that the transverse processes of the dorsal vertebræ take a direction most nearly corresponding to that which obtains in *Stagonolepis*. Without attaching too much weight to this circumstance, it will be seen by and by that it is worth while to bear it in mind.

The second peculiarity to which I have directed attention may perhaps be the result of the early anchylosis of the caudal transverse processes with the neural arches. However this may be, the character in question is a very exceptional one, and long led me to hesitate in regarding the vertebræ in question as really caudal.

The gradual divergence from the strictly Crocodilian type of organization which is manifest in the remains to which I have just adverted reaches its climax in the next part I have to mention*. A fragment of bone protruding from the surface of one of the blocks of sandstone from Lossiemouth was the last to attract my attention of all the fossils which have been sent from Elgin. Certain indications convinced me that, notwithstanding the extreme fragility of the bony substance and the depth to which it seemed to penetrate

* See the final Note, p. 459.

into the sandstone, it was worth some trouble to work out this bone completely, and having succeeded, by dint of careful chiselling, in removing a considerable quantity of superincumbent matrix without damage to the fossil, I was rewarded by the view of the nearly entire ventral face of a coracoid bone, of a form very unlike what might have been anticipated. For this bone, far from having the transversely elongated form more or less constricted in the middle, which is exhibited by the corresponding part in all the true *Crocodilia* with which I am acquainted, whether mesozoic, cainozoic, or recent, is almost elliptical in outline, and the long axis of the ellipse, which is nearly parallel with the middle line, is to the short transverse axis as 6 to about 4. The articular surface for the humerus is crushed and partly broken away, and a part of the anterior external edge is incomplete. The posterior edge of the bone presents a deep excavation close to the articular end; and, if two lines were drawn, one longitudinally through the deepest part of the notch, and the other transversely through the greatest transverse diameter of the bone, they would cut one another in the midst of a circular foramen, which corresponds with the coracoid foramen of Crocodiles and many Lizards. I find no coracoid so similar to this as that of *Hylæosaurus**.

*Jaw and Teeth.*—The only remaining fossil which bears strongly upon the question of the affinities of *Stagonolepis* is the impression of a fragment of what I conceive to be the lower jaw, exhibiting the remains of some eight or nine alveoli. The impressions of the teeth contained in four of these, situated near the anterior end of the fragment (which may or may not have been its natural termination), are tolerably perfect. The third tooth is the largest, though, judging by its alveolus, the fourth, which is wanting, must have been larger than even the third. The second tooth is emerging from the jaw, not more than half its length being visible beyond the alveolar edge.

The impression of the surface of the jaw is, though imperfect, an inch and a half deep in some places, while the longest tooth projects two and a quarter inches beyond the alveolar margin; so that this tooth was probably at least three inches long, while its greatest transverse diameter amounts to very little less than five-eighths of an inch.

The upper third of each tooth is slightly recurved, and the apex appears to have been lancet-shaped when young, but more obtuse and rounded afterwards. At the apex and for some distance below it (half an inch in the longest or fourth tooth) the surface of the tooth is smooth and polished, but further down numerous longitudinal ridges, with rounded surfaces, separated by very narrow grooves, make their appearance, and increase slightly in strength down to the alveolar margin. As might be expected from the subcylindrical figure of the tooth, the ridges do not increase in width towards its root.

The teeth appear to have had broad anterior and narrow poste-

* See concluding Note, p. 459.

rior faces, but there is no evidence that they possessed any definite cutting edge. The manner in which the teeth are crushed and cracked towards their alveolar ends indicates the existence of a large pulp-cavity, bounded by comparatively thin walls.

The alveoli are quite distinct from one another. The bony substance of the jaw has left such an impression as leads to the belief that it must have had a coarsely fibrous structure, more like that of a fish than that of a reptile. There is also a remarkable irregularity and want of parallelism about the disposition of the teeth, the fifth being greatly inclined backwards, and the second having a similar, though less marked, obliquity.

There is no positive proof that this fragment of a jaw belonged to *Stagonolepis*; but, as I have already stated, no vertebrate remains save those of this reptile have hitherto been found in the Findrassie quarry, whence the specimen was obtained, and the external characters and mode of implantation of the teeth are wholly unlike those of any of the large, probably piscine, teeth (of *Dendrodus, e.g.*) which have been discovered in the neighbouring beds of the Old Red Sandstone. (See the final Note, p. 459.)

If this jaw belonged to the same animal as that to which even the largest of the vertebræ which have been discovered belonged, the size of the teeth is remarkable, for the longest is considerably more than twice as long as the centrum of such a vertebra. On the other hand, it must be recollected that the teeth of some of the ancient *Teleosauria* are extremely long in proportion to the jaw, and in other respects present resemblances to those contained in the fragment just described; while it is also possible that this fossil may have formed a part of an individual larger than any of those whose vertebræ have as yet come to light. As the evidence stands at present, I see no reason to doubt that the jaw belonged to *Stagonolepis.*

Assuming that *Stagonolepis* had the same general proportions as a crocodile—as, from the characters of the jaw, femur, and caudal vertebræ, we have every reason to believe was the case—the largest remains I have met with, excluding the jaw just mentioned, indicate an animal about eight feet long. (See Note, p. 459.)

*Affinities of the Stagonolepis.*—With regard to the affinities of the Reptile whose leading structural peculiarities have been detailed in the foregoing pages, I think it is clear that *Stagonolepis* is, in the main, a Crocodilian Reptile. Its dermal armour, its sacrum, its scapulæ, are eminently crocodilian; its femur and dorsal and caudal vertebræ are also crocodilian, though presenting small aberrations from the pure type. The teeth, though more divergent, are crocodilian in their mode of implantation and some other respects. The coracoid, on the other hand, is lacertilian or dinosaurian*; and finally, if one may safely judge from the few remains which have hitherto presented themselves, the bones of the feet were neither crocodilian nor dinosaurian nor lacertilian.

* See the Note at the end of the paper.

I am at a loss to find an exact parallel for this peculiar combination of characters in any group of recent or fossil *Reptilia*. Among the tertiary and recent reptiles I know of nothing at all like it; and all the mesozoic *Crocodilia* with whose dermal armour that of *Stagonolepis* exhibits such a close resemblance, present no important divergence from the typical crocodilian structure of the coracoid, while their slender feet have undergone the opposite modification to that which appears to have taken place in *Stagonolepis*. The *Enaliosauria* and *Pterodactylia* afford us no terms of comparison; and from the *Dinosauria*, with which *Stagonolepis* presents one or two similarities, it is broadly separated by the especially crocodilian characters of its scutes and sacrum. These characters equally separate it from all the Triassic and Permian *Reptilia* which have hitherto been described. What little we know, at present, of the laws by which the distribution of life in past time was governed, does not seem to me to enable us to deduce from the existing data any conclusion as to the precise age during which the Elgin Reptile lived. Such a combination of characters as it presents would, I apprehend, be in perfect keeping with the known Reptilian Fauna of any epoch from the Wealden downwards.

*Foot-prints* (Pl. XIV. figs. 4 & 5).—I have intentionally deferred to the end of my communication the description of the footmarks which have been observed upon the sandstones of Cummingstone, because, although they are certainly the tracks of Reptiles, there is, strictly speaking, no proof whatsoever that they were produced by the particular Reptile *Stagonolepis*, no fragment of which has been detected in the Cummingstone quarries. It is desirable therefore that the foot-marks should be considered quite independently, though it may be instructive to inquire what positive and negative evidence there is in favour of thinking them to be the work of *Stagonolepis*.

Although a considerable series of these tracks has passed under my inspection, I have only seen two foot-marks which are so clear and distinct as to satisfy my mind that they fairly represented the figure of the foot. The two impressions in question form part of a continuous track, evidently made by the same animal, and exhibiting three pairs of right-foot prints (of the fore and hind foot on each side) and two pairs of left-foot prints.

(*Fore Foot.*)—The most distinct impression of the anterior foot (fig. 4) is the middle one of the three on the right side. Its greatest breadth is $2\frac{3}{4}$ inches, its greatest length $3\frac{3}{4}$ inches. The plantar surface of the foot measures $1\frac{1}{2}$ inch in its greatest antero-posterior diameter. The impressions of five digits are visible; and the proximal joints of the third digit, taken together, equal rather more than an inch in length, while the impression of its terminal joint is $1\frac{1}{4}$ inch in length.

This plantar impression is on the whole transversely oval, its anterior boundary presenting a tolerably even convexity forwards, while the posterior boundary, equally, or more, convex backwards, presents an emargination opposite the base of the middle digit. A line drawn from the emargination to the base of the fourth digit would divide the plantar impression into a shallow outer portion and a more deeply concave inner portion. A line drawn from the emargination to the interspace between the first and second digits, again, would divide the concave inner surface into a deeper external portion and an internal portion, the latter gradually shallowing towards the inner side, and passing into the impression of the inner digit, which diverges so much from the direction of the others, and seems to have been comparatively so thick and short, that it might well be termed a thumb. The proximal portion of this thumb seems at first to terminate in a strong curved impression convex outwards and forwards, and deepest internally, which has somewhat the shape of a comma set transversely ( ⁀ ).

The distance from the emargination to the end of this impression is $1\frac{7}{8}$ inch; beyond it is an interval of $\frac{3}{8}$ths of an inch; and then follows a shallow longitudinal mark, $\frac{3}{4}$ inch long and nearly $\frac{1}{4}$ inch broad, which takes a direction nearly parallel with that of the ungual phalanges of the other digits, and terminates opposite the base of the ungual phalanx of the second digit.

The last-mentioned features are only to be made out by examining the tracks very carefully by artificial, or by very oblique natural, light*. Whether, as I originally supposed, the deep comma-shaped impression is the mark of a nail covering the second phalanx, or whether it has been produced by the first phalanx,—the longitudinal mark being the true impression of the second phalanx,—is a point I will not take upon myself to decide. A concave surface, rising anteriorly, connects the impression of the proximal moiety of the first digit with that of the proximal phalanges of the second digit. This impression, which is about an inch long, is very deep, especially at its posterior end, and consists of two divisions, joining at an angle, which is open outwards. The posterior division is shorter and broader than the anterior, and the two would answer very well to two phalanges: the anterior division is succeeded by a third elongated and much fainter impression, about $1\frac{1}{4}$ inch long, broad and tolerably deep at the base, but gradually tapering and fading away anteriorly. This appears to be the impression of the ungual phalanx of the digit; so that it would appear that there were three phalanges in this digit, that the direction of the proximal one is straight forwards, that of the middle phalanx forwards and outwards, and that of the distal or ungual phalanx still more outwards; so that the three describe a kind of curve, convex inwards.

The impression of the third digit is like that of the second, except that the distance between what appears to be the end of the proximal phalanx and the base of the ungual phalanx (corresponding with the 'anterior division,' spoken of above) amounts to fully $\frac{3}{4}$ inch, while in the second toe it is not more than $\frac{1}{2}$ inch. Perhaps there were two phalanges here. The impression of the ungual phalanx is, as was stated above, $1\frac{1}{4}$ inch long.

* I had not done this when my account of *Stagonolepis* was given to the Society, and hence, in the abstract of my communication, the comma-shaped impression is described as the mark of a "thick, short, and much-curved nail."

The impression of the fourth toe is shorter than that of the third; but, as the ungual phalanx is of nearly the same length as in the third, the shortening would appear to be due either to the shortening, or to the smaller number, of the proximal phalanges.

The impression of the fifth digit does not quite reach to the base of the ungual phalanx of the fourth. The impression of the terminal phalanx is less distinct, and, like the fourth, the stirring up of the sand has rendered it indistinct at its proximal end.

The surfaces of the interspaces between the digits are so peculiarly rounded that there can be little doubt they were moulded by a connecting membrane or web, though the precise boundaries of this interdigital membrane are not traceable.

(*Hind Foot.*)—The ends of the toes of the posterior impression of the pair to which that just described belongs infringe upon the posterior and outer part of the plantar margin of the anterior impression. It is but a confused mark, however, and the true characters of the imprint left by the hind foot are much better shown in the pair behind these, where the sand was evidently firmer when the animal walked over the surface.

This impression (fig. 5) measures about $2\frac{1}{4}$ inches transversely, and longitudinally $2\frac{1}{2}$ inches, or a little less.

The plantar surface measures $1\frac{1}{8}$ inch from before backwards, and its posterior edge is nearly semicircular and not emarginated. The anterior edge is nearly straight. It gives off four deepish longitudinal impressions, answering to as many digits. Of these the middle two measure $1\frac{1}{8}$ inch in length, and are consequently somewhat longer than the inner and the outer, which are hardly more than $\frac{3}{4}$ inch long.

The ungual phalanges appear not to have attained a length of $\frac{5}{8}$ths of an inch in the longest digits, and all four digits appear to have been connected by a web. The anterior and external angle of the plantar surface projects $\frac{3}{8}$ths of an inch beyond the base of the fourth digit, as if there had been a rudimentary fifth digit.

The length of the stride, from the hinder edge of one fore-foot print to that of the next, is just twelve inches. The space covered by the track transversely to its length, measured from the outer edge of one foot-mark to a line prolonging that of the foot-mark on the opposite side, is about ten inches.

On the same slab as that on which these tracks occur there are a number of other foot-marks, some of which are nearly eight inches long, while others hardly exceed an inch in length. They are all, however, more or less imperfect, either from the condition of the surface at the time they were impressed, or from the subsequent superposition of other impressions. The only feature which they exhibit better than those just described is the mark of the interdigital membrane, which in some of these foot-marks is very obvious, and exhibits strong transverse wrinkles, concave forwards.

All the other foot-tracks from Cummingstone which have come under my notice are either mere unintelligible marks, or may be explained by the perfect footsteps I have just described; so that at present I see no reason for believing that the tracks were caused by more than one species of Reptile. The great apparent differences between some of these foot-marks and others appear to be referable to the varying condition of the sand upon which the tracks were made.

In the length of the impressions made by the ungual phalanges, and in the large size of the anterior as compared with the posterior foot, the Cummingstone tracks are, so far as I know, unlike those of any known Crocodilian or Chelonian (?) reptile; but it must be confessed that there is a great want of recent materials in attempting to study comparative ichnology. The foot-marks in question are not Cheirotherian, nor do they present any marked similarity to the singular tracks found at Shrewley Common. The resemblance to some of the Ichnites (*Chelichnus, e. g.*) of Dumfriesshire, though closer, by no means amounts to identity. But I defer for the present a more extended comparison, which could only be made intelligible by numerous figures.

As to the question whether these tracks were or were not produced by *Stagonolepis*, I will only say that I see no reason for asserting that they were not, while there is some ground for believing that they were so produced. There is reason to believe that *Stagonolepis* had a short and broad metatarsal and metacarpal region and long ungual phalanges. The foot-prints have broad palmar and plantar impressions and long claw-marks. The shape of the claw-mark answers very well to that of the sole ungual phalanx which has been discovered; but I must remark that the length of that phalanx is somewhat too great for any foot-print yet discovered.

The Crocodilian number of toes, again, combined with the non-Crocodilian proportions of the feet, harmonizes very well with the modified Crocodilism (if I may coin a word) of the organization of *Stagonolepis*.

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NOTE.—Unless the contrary is expressly stated, the preceding paper remains in all essential respects the same as when it was sent in to the Society. Since that time, however, several months have elapsed, and, thanks to the exertions of my indefatigable friend Mr. Gordon, much new material has come to light. On the other hand, I have submitted the recent *Crocodilia* to such a revision as the time at my disposal would allow, and I have published some of my results in an Essay "On the dermal armour of *Jacare* and *Caiman*, with notes on the specific and generic characters of recent *Crocodilia*," published in the 'Proceedings of the Linnean Society' for February 1859.

The sum of my conclusions from the various kinds of evidence thus obtained is, that the divergence of *Stagonolepis* from the Crocodilian type is even less than I had imagined; and in some characters, such as the form of the posterior maxillary teeth, *Stagonolepis* is more like a modern Crocodile than a Teleosaurian.

A very fine specimen of a coracoid, recently sent by Mr. Gordon, convinces me that the differences from the Crocodilian type of structure which I have ascribed to this bone in *Stagonolepis* do not really exist. I am obliged to take this opportunity of distinctly asserting that the only two coracoids of *Stagonolepis* which have been discovered have been sent to me direct from Elgin, that I have worked them out from the matrix with my own hands, and that no anatomist had seen the one described in my paper before the publication of my account of its structure. That account, however, is incomplete, the new specimen showing that a considerable part of the bone was wanting, and that, when perfect, it is far more Crocodilian than Lacertilian in its characters.

The remarkable new Reptile, *Hyperodapedon Gordoni*, which I have briefly characterized in a note to Sir R. I. Murchison's paper (see p. 435), is of paramount interest; for while, on the one hand, its discovery justifies my hesitation in at once ascribing the Cummingstone foot-marks to *Stagonolepis*,—on the other, its marked affinity with certain Triassic reptiles, when taken together with the resemblance of *Stagonolepis* to mesozoic *Crocodilia*, leads one to require the strongest stratigraphical proof before admitting the palæozoic age of the beds in which it occurs.

Finally, I may add, that *Stagonolepis* attained a much greater size than my former materials warranted me in believing. Some of the recent discoveries lead me to suppose that it reached 16 or 18 feet in length.

While this Note was passing through the press, the Monograph of D'Alton and Burmeister ('Der fossile Gavial von Boll,' 1854) came into my hands. The excellent memoir by these authors on the ancient *Mystriosaurus bollensis* is preceded by a valuable essay on the organization of recent *Crocodilia*, including the best account I have met with of the ventral dermal armour (p. 29). The transverse sutures dividing the ventral scutes, and their mode of articulation, are noted; but, on the other hand, it is said that only the three or four outer series of ventral scutes have pitted surfaces, and the authors suppose that the ventral armour which they describe (and which is apparently that of a *Jacare*) is found in all recent Crocodiles. I can find no reference to the fact that the great majority of living *Crocodilia* are wholly devoid not only of ventral bony armour, but of *articulated* dorsal scutes.—July 5, 1859. T. H. H.

## DESCRIPTION OF PLATE XIV.

Fig. 1. Plaster-cast of a portion of the specimen of *Stagonolepis* originally described by Prof. Agassiz. *a*, anterior ends of the *flat scutes*; *b*, their posterior ends.

Fig. 2. Gutta-percha cast of the impression of a *broad-angulated scute* (not that described in the text), from Findrassie.

Fig. 3. Gutta-percha cast of an impression of an *irregular-angulated scute*, from the same locality.

Fig. 4. Right anterior foot-print, from Cummingstone.

Fig. 5. Right posterior foot-print, from the same series of tracks.

### 3. *On* Fossil Foot-prints *in the* Sandstone *at* Cummingstone. By S. H. Beckles, Esq., F.G.S.

[Abstract.]

Mr. Beckles, during a late tour in the Highlands, examined the Sandstone-quarries at Covesea, near Elgin; and, having exposed and removed several square-yards of the Sandstone-slabs bearing fossil foot-prints at this place, has sent a large collection of them to London, but has not yet had the opportunity of studying them in detail. Mr. Beckles says that he has secured several varieties of footsteps, differing in size and form, and in the number of the claws, which vary apparently from 2 to 5. One foot-print, of a circular shape, measured 15 inches in breadth. Some of the smaller foot-prints are evidently formed by young individuals of the same species that made some of the larger marks. Some of the prints have been left, in the author's opinion, by web-footed animals.

Most of the surface-planes of the rock, at different levels, bear foot-marks. The majority of the tracks, Mr. Beckles says, are uniserial, the double (or quadrupedal) series being exceptional.

Mr. Beckles noticed also impressions of rain-prints, well marked on some of the surface-planes, and indicating the direction of the wind blowing at the time of the rain-fall.

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### 4. *On the* Succession *of* Rocks *in the* Northern Highlands. By John Miller, Esq.

Communicated by Sir R. I. Murchison, V.P.G.S.

(The publication of this paper is unavoidably postponed.)

[Abstract.]

Mr. Miller in this communication explained the history of our knowledge of the geology of this district; and, having given in detail an examination that he made of the coast last autumn, he drew particular attention to the faithful and comprehensive descriptions of the Old Red district by Sedgwick and Murchison in former years, and showed that his own observations quite coincide with the results of Sir Roderick Murchison's late correlation of the Gneissic, Cambrian, Silurian, and Old Red strata of the coasts of Sutherland, Ross-shire, and Caithness.

In conclusion, Mr. Miller pointed out that the Durness Limestone and the fossiliferous beds of Caithness were still open fields for careful and energetic explorers.

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THE

# QUARTERLY JOURNAL

OF

# THE GEOLOGICAL SOCIETY OF LONDON.

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## PROCEEDINGS

OF

## THE GEOLOGICAL SOCIETY.

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January 5, 1859.

John Ford, Esq., Market-Raisin, Lincolnshire; Charles Francis Humbert, Esq., Watford; and Joshua Frey Jepherson, Esq., Barrister-at-Law, Sydney, New South Wales, were elected Fellows.

The following communications were read:—

1. *On* Fossil Plants *from the* Devonian Rocks *of* Canada. By J. W. Dawson, LL.D., F.G.S., Principal of M'Gill College, Montreal.

In 1843–44, Sir W. E. Logan ascertained, and published in his Report* for the latter year, the occurrence of a series of beds of Devonian age in the Peninsula of Gaspé, Lower Canada, containing fossil plants, apparently of terrestrial origin, and some of them evidently *in situ*. Nothing was done toward the precise determination and description of these remains until 1856, when Sir William kindly permitted the writer of this paper to examine his collection, and to describe before the American Association for the Advancement of Science the most interesting specimen contained in it—a fossil trunk exhibiting a very remarkable and previously undescribed coniferous structure†. The other specimens in the collection were so fragment-

* Report of Progress of Canadian Geological Survey, 1844, p. 36, and Appendix.
† Proceedings of American Association, 1856, p. 174.

ary or obscure, that it was not deemed expedient to attempt their description before studying them (as all fossil plants should, when practicable, be studied) in the rocks in which they occur. With this view I visited Gaspé in the past summer, and examined the localities indicated on the plans and sections of the Geological Survey. The facts and specimens thus obtained will probably be fully described and illustrated in one of the forthcoming Decades of Canadian Fossils; and in the meantime I propose to notice some of the species observed, which appear to be of especial interest in the present state of our general knowledge of the Devonian flora.

Before proceeding to these descriptions, it may be necessary to state that the deposit in which the fossils occur consists of sandstone and shale, of various colours and textures, with some conglomerate and thin-bedded coarse limestone, and a seam of bituminous coal, one inch in thickness. The whole series is estimated by Sir W. E. Logan at 7000 feet of vertical thickness. It rests on Upper Silurian rocks, and underlies unconformably the conglomerates which here form the base of the Carboniferous system. Some of the beds, especially in the lower part of the series, contain marine fossils of Lower Devonian forms, which are now in process of examination by Mr. Billings, of the Geological Survey. The greater part of the beds are, however, destitute of marine fossils, and present appearances indicative of shallow water and even of land-surfaces. Some of the species of plants occur throughout the whole thickness; but the bed of coal and most of the plants *in situ* are found in the lower and middle portions of the series. Detailed sections and descriptions of the beds will be found in the Report above referred to.

### 1. Psilophyton, gen. nov. (Figs. 1 & 2.)

*Lycopodiaceous plants, branching dichotomously, and covered with interrupted ridges or closely appressed minute leaves; the stems springing from a rhizoma having circular areoles, sending forth cylindrical rootlets. Internal structure: an axis of scalariform vessels, surrounded by a cylinder of parenchymatous cells, and by an outer cortical cylinder of elongated woody cells (prosenchyma). Fructification probably in lateral masses, protected by leafy bracts.*

The most remarkable and interesting plant of the formation is one which, I believe, has frequently been observed and described elsewhere from fragmentary specimens, but which occurs in the Gaspé sections in a state of perfection unusual with palæozoic plants. It is characterized by slender, bifurcating, ridged stems, proceeding from a horizontal rhizoma, which sends forth numerous rootlets. The rhizomata, evidently *in situ*, clothe some beds of indurated clay with a mat of creeping and occasionally bifurcating cylindrical stems, filling the beds below with their vertical rootlets. They attain a diameter of an inch or more, though usually smaller, and a length of at least three feet. They are irregularly dotted with minute linear punctures, the marks probably of ramenta; and at intervals there are circular areoles with central pits, like those of *Stig-*

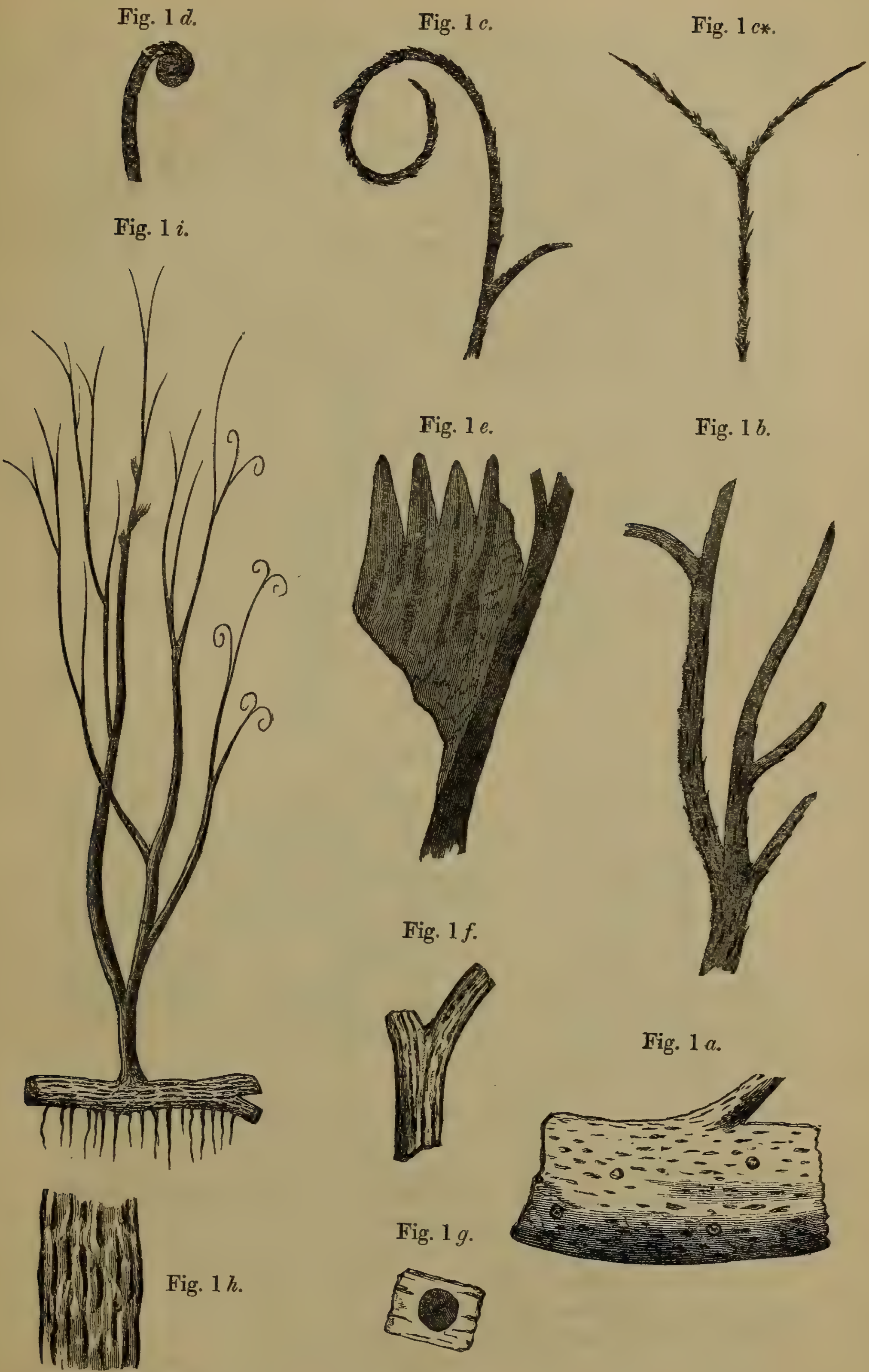


Fig. 1. *Psilophyton princeps.* *a*, rhizome; *b*, stem; *c*, *c**, termination of branches; *d*, vernation; *e*, fructification; *f*, stem, twice nat. size; *g*, areole of rhizome; *h*, large stem, nat. size; *i*, restoration.

*maria*, but irregularly disposed, and giving origin to the roots, which, however, unlike those of *Stigmaria*, subdivide in descending into the soil. Apart from the stems, these rhizomata might be included in the genus *Karstenia* or *Halonia*, or even as abnormal species in *Stigmaria* (figs. 1 *a*, *g*). The aërial stems vary from a fourth to a tenth of an inch in diameter at their origin, rise obliquely from the rhizoma, and bifurcate very regularly. The extreme points divide nearly at right angles, and in some, probably young, branches the ultimate branchlets bend into a spiral curve with a somewhat unilateral arrangement of the leaflets. In the shale overlying the small coal-seam above-mentioned, there are immense numbers of these little branchlets, rolled so closely as to resemble spiral shells. They probably indicate a circinate vernation like that of ferns. (See figs. 1 *b*, *c*, *d*.) The surface of the stems is very smooth and glossy, quite destitute of scars, but marked with numerous interrupted ridges spirally arranged, and sometimes seen to project a little at the upper ends, as if rudimentary leaves. This leaf-like character is more distinct towards the extremities of the branches; but the leaves are not sufficiently well preserved to show anything more than that they are slender and acicular. (Figs. 1 *c*, *f*, *h*, p. 479.)

The greater part of the specimens are flattened, with the epidermis alone preserved in a coaly state; but a few fragments were found

Fig. 1 *k*.


Fig. 1 *l*.


Fig. 1 *m*.

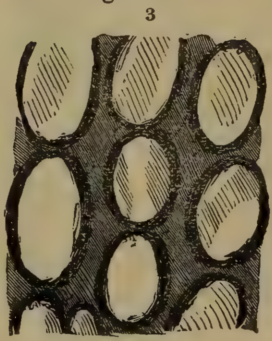


Fig. 1 *n*.


Fig. 1 *k*, longitudinal section of stem, nat. size; *l*, cortical cells (300 diams.); *m*, parenchyma (300 diams.); *n*, scalariform tissue of axis (300 diams.).

with the internal structure remaining. It consists of a slender axis of scalariform vessels, surrounded by a space now occupied by calc-spar, but showing in parts the remains of a loose cellular tissue. Externally to this is a cylinder of well-preserved, elongated, woody cells, without distinguishable pores, but with traces of very delicate spiral fibres. (Figs. 1 *k*, *l*, *m*, *n*.)

The structure and external appearance above described indicate affinities with the *Lycopodiaceæ*, and especially with the genus *Psi-*

*lotum**, with which these plants very closely correspond in all except their rhizomes and the circinate terminations of the branchlets. The name proposed above is intended to express this relation, as well as the most apparent distinction between these plants and those of the genera *Lycopodites* and *Selaginites*†. To the species above-described I would give the name of *Psilophyton princeps*. I have attempted a restoration of its general appearance in fig. 1 *i*.

Some of my specimens appear to indicate a second species, characterized by more robust stems, more finely ridged, and having slender alternate branches, which bifurcate frequently and usually bend

Fig. 2 *a*.

Fig. 2 *b*.

Fig. 2. *Psilophyton robustius*. *a*, stem; *b*, markings of stem (nat. size), ligneous surface.

downward. The specimens are not well preserved, but are very distinct from *P. princeps*, while probably generically related to it. I would name this species *P. robustius* (figs. 2 *a*, *b*).

Neither of the species exhibit distinct fructification. Certain obscurely cuneate carbonaceous spots attached to the sides of the branches of *P. princeps* are, perhaps, of this character; and the ob-

* See Brongniart, Vég. Fos. vol. ii. pls. 6 & 11. I have been favoured by Prof. Gray, of Harvard College, with specimens of *P. flavidum* from Tahiti and *P. triquetrum* from Australia, which closely resemble the fossils in structure and surface-markings.

† I should have preferred the term "Psilotites;" but this has been preoccupied by a Jurassic plant, of which, however, I cannot find any detailed description. See Unger, Gen. et Spec. &c. p. 279; Brongniart, Tableau des Genres, p. 41.

ject represented in fig. 1 *e*, which appears to be thus attached, may be an example in better preservation than usual. It consists of four thick lanceolate leaves or bracts with single midrib, arising from a flattened carbonaceous patch, which shows traces of similar leaves on its surface. These leaves or bracts have evidently enclosed the fructification of some lycopodiaceous plant; and, from their association with *Psilophyton princeps*, I regard it as highly probable, though by no means certain, that they belong to that species.

The rhizomata of *Psilophyton princeps* occur *in situ* in a number of argillaceous beds, in a manner which shows that they crept in immense numbers over flats of sandy clay, on which their graceful stems must have formed a thick, but delicate, herbage, rising to the height of from two to four feet. The rhizomes and the bases of the stems may possibly have been submerged; but I should infer, from the appearance and structure of the latter, that they were rigid, woody, and perhaps brittle. In many beds in which the rhizomes have not been distinctly preserved, the vertical rootlets remain, producing an appearance very similar to that of the Stigmarian underclays of the coal-measures. Sir W. E. Logan has noted in his detailed sections numerous cases of this kind.

When broken into fragments and imperfectly preserved, *Psilophyton princeps* presents a variety of deceptive appearances. When perfectly compressed in such a manner as to obliterate the markings, it might be regarded as a dichotomous fucoid or a flattened root. When decorticated and exhibiting faint longitudinal striæ, it presents, especially when the more slender branchlets are broken off, the aspect of a frond of *Schizopteris* or *Trichomanites*. When rendered hollow by decay, it forms bifurcating tubules, which might be regarded as twigs of some tree with the pith removed. Lastly, the young plants might be mistaken for ferns in a state of vernation. In all conditions of preservation, the stems, rhizomes, and rootlets, if separated, might be referred to distinct genera. I have little doubt therefore that many imperfectly preserved Devonian plants of this general form, noticed under various names by authors, may belong to this genus, and some of them to the species above described. In particular I may refer to certain dichotomous fucoids in the genera *Fucoides* and *Chondrites*; to a plant from the Hamilton Group of New York, figured by Vanuxem in his Report, p. 161; to the dichotomous roots from Orkney and Caithness described by Mr. Salter in the 'Proceedings' of this Society for last year; and to the bifurcating plants with curved tendril-like branchlets figured by Hugh Miller, 'Old Red Sandstone,' plate 7, and 'Testimony of the Rocks,' p. 434. From the description in the former work, Chap. 5, it would appear that the author had observed not only the stems but the rhizomes with their Stigmaria-like areoles, though without suspecting them to belong to the same plant. I have little doubt therefore that materials exist in the Old Red Sandstone of Scotland for the reconstruction of at least one species of this genus. Various fragments which I have collected induce me to believe that it may be found also in the Lower Coal-measures.

I have noticed above the resemblance of flattened specimens of *Psilophyton* to ferns of the genus *Trichomanites* (Gœppert). To this genus, indeed, I was disposed to refer the specimens, until I found that the internal structure was lycopodiaceous, and that the branching filaments are true branchlets covered with minute leaves. A comparison of the plants above described with *Trichomanites Beinertii* of Gœppert, and *Sphenophyllum* (*T.*) *bifidum* of Lindley and Hutton, will show at a glance the strong resemblance that subsists; and, since the specimens on which these species are founded do not appear to have exhibited either internal structure or venation, I think it still admits of a doubt whether they are really ferns. By way of further caution on this point, I may remark that in flattened stems, either of *Psilotum* or of its ancient relative, the slender woody axis may leave a mark resembling the nervure of a leaf, and thus complete the resemblance to a frond of *Trichomanes*.

Since writing the above, Professor G. S. Newberry has kindly pointed out to me the close resemblance between the first species above described and *Haliserites Dechenianus* of Gœppert ('Flora der Uebergangsgebirges,' p. 88). I can scarcely doubt that this so-called fucoid is in reality a plant of the genus above described, but in such a state of compression that the stem appears like a narrow frond, and the woody axis as a midrib. As this plant is said to occur very abundantly at certain levels in the Devonian Series of the Rhine, if my suspicions as to its nature be correct, further examination might disclose its rhizomes, leaves, or fructification*.

## 2. Lepidodendron. (Fig. 3.)

A single species of this genus is found rather plentifully in the beds containing the plants just described, and is distinct from any that I have observed in the Coal-formation. The specimens observed were all of small size and fragmentary, nor was their state of preser-

Fig. 3 *a*. Fig. 3 *b*. Fig. 3 *c*. Fig. 3 *d*.

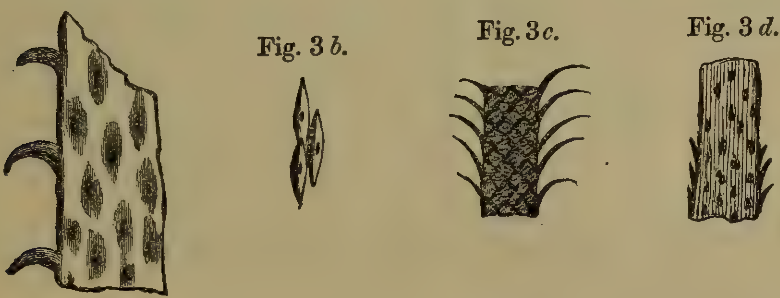

Fig. 3. *Lepidodendron Gaspianum*. *a*, decorticated stem and leaves; *b*, areoles; *c*, small branch and leaves; *d*, decorticated branch and leaves.

vation very good, though most of them were accompanied by the leaves. In specimens about two inches in diameter, the areoles are

* It is possible that some of the fragments, from the Devonian of the Thüringerwald, included by Prof. Unger in his order *Rhachiopterideæ* may be allied to *Psilophyton*. (See Denkschr. Kais. Akad. Wissen. Wien, vol. xi. p. 139.)

two lines in length and one in breadth, and placed closely together. They are elliptical, acuminate, with central leaf-scar, the form and markings of which could not be perceived. The leaves are thick at the base and short, slightly ascending, and then curving downward. The branches are slender, straight, and very uniform in thickness in the portions observed. This plant may be identical with the *L. Chemungense* of Hall, from the Devonian rocks of New York; but I am not aware that any specimens of that species hitherto observed show the leaf-scars or leaves; and, when these are obtained, should the present species prove distinct, I would name it *L. Gaspianum**. Its characters, as above stated, are represented in figs. 3 *a–d*.

3. Prototaxites, gen. nov. (Fig. 4.)

*Woody trunks with concentric rings of growth and medullary rays. Cells of pleurenchyma scarcely in regular series, thick-walled, and cylindrical, with a double series of spiral fibres. Disc-structure indistinct in the specimens observed.*

I propose the above generic appellation for a tree having the spirally marked cells characteristic of the genera *Taxites* and *Spiropitys* of Gœppert, but differing from any conifer known to me in the cylindrical form and loose aggregation of the wood-cells, as seen in the

Fig. 4 *a*. Fig. 4 *b*. Fig. 4 *c*.

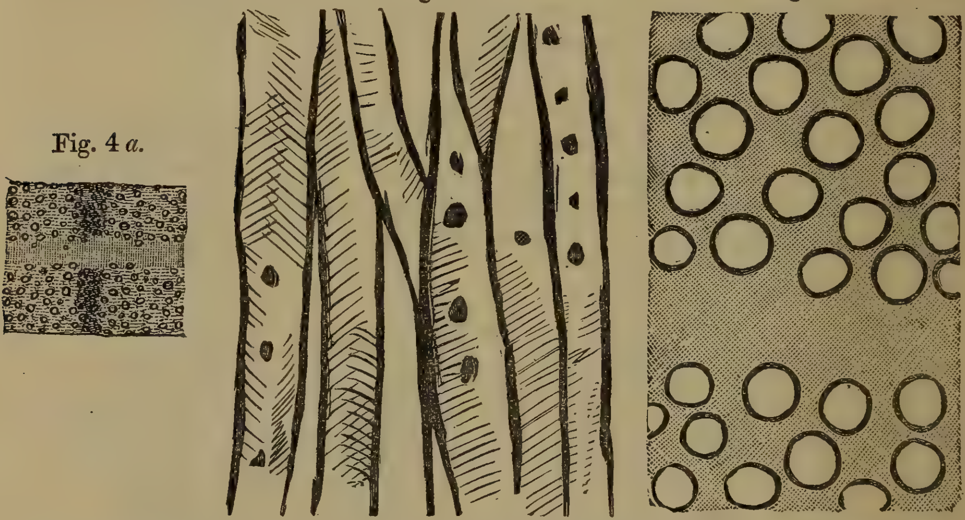

Fig. 4. *Prototaxites Logani.* *a*, cross-section, magnified 40 diams., showing growth-line and medullary ray; *b*, longitudinal section (300 diams.); *c*, transverse section (300 diams.).

cross-section, in which particular it more nearly resembles the young succulent twigs of some modern conifers than their mature wood. A fine silicified trunk of this tree was brought from Gaspé by Sir

* *L.* (*Sagenaria*) *Veltheimianum*, another ancient and widely distributed species, resembles the above in the form of the areoles and position of the scars; but the leaves and young branches differ, and my specimens show no median furrow in the areoles. *L. nothum* (Unger) also seems closely allied.

W. E. Logan, and was shortly described in the 'Proceedings of the American Association' for 1856.

The specimen is nine inches in diameter, and presents throughout a series of rings of growth, rather more than one-tenth of an inch in average thickness. Under the microscope, the cross-section exhibits cells perfectly circular in outline, not crowded, but becoming much smaller at the margins of the rings of growth, where some large irregular openings perhaps represent resin-ducts. The medullary rays are marked by clear structureless spaces. In the longitudinal section, parallel to the medullary rays, the wood-cells are seen to be much elongated, and to terminate in conical points; and their sides are covered with the remains of a double series of spiral fibres, among which are a few scattered roundish spots, which perhaps indicate a single row of discs*. The cells of the medullary rays have been entirely disorganized; but the space which represents them in a tangential slice, shows that they must have consisted of several rows of cells. (Figs. 4 *a–c*.)

In my late visit to Gaspé, I was so fortunate as to find a second tree of this species imbedded in the strata, though having its structure in a less perfect state of preservation than the specimen above described. It was in a prostrate position, the trunk lying S.W. and N.E., in a thinly bedded, crumbling, pyritous sandstone. The trunk is silicified, one foot five inches in its greatest diameter, and eleven inches in its least, the difference being due to compression; a branch five inches in diameter sprang from its side. On the external surface was a thin layer of crumbling coal, probably representing the bark. No pith was perceptible; but there was a channel or depression along the upper surface, as if a pith-cavity had existed and, when the wood became softened by decay, had given way to pressure. The age of this tree, as indicated by its rings of growth, would be about one hundred and fifty years; so that, though the tissue appears lax, it was not of more rapid growth than in modern conifers. The growth-rings also in the specimen previously described, as well as in this, are well marked, indicating a decided difference of temperature in the seasons of the Devonian year. I cannot propose for this monarch of the old Devonian forests of Gaspé a better or more appropriate name than that of its discoverer, and shall therefore name it *Prototaxites Logani*.

With respect to the affinities of the genus, I can only say that the markings on its wood-cells most nearly resemble those of the two genera of fossil Taxine trees above-mentioned, which are, however, found in much more modern geological formations. Among recent trees known to me by specimens or figures of their tissues, *Taxus baccata* and *Torreya taxifolia* most nearly resemble the Gaspé fossil. In the meantime, therefore, it may be included in the subfamily *Taxineæ*.

I could detect no leaves or fruit likely to belong to the species;

* This disc-like structure was first pointed out to me by Mr. Poe, of Montreal, a very zealous and successful microscopist.

but this is not wonderful, since in the Coal-formation the wood of conifers is very abundant, while their foliage is extremely rare.

Before leaving this ancient taxine conifer, it may be useful to notice the deceptive appearances which its wood presents when imperfectly preserved. In some parts of my second specimen the woody tissue has been entirely obliterated, and is replaced by a kind of oolitic concretionary structure, apparently connected with the presence of iron-pyrites. In other portions the wood seems to have been resolved into a homogeneous paste before silicification; and this, being moulded on minute granular crystals of quartz, assumes the aspect of a tissue of fine parenchymatous cells—a deceptive appęarance very common in badly preserved fossils penetrated by calcareous or siliceous matter. In other parts of the specimen the cell-walls remain, but in an opaque coaly condition, which conceals their spiral fibres and discs. I am not quite certain that this last form may not represent the natural state of the heart-wood of the tree. In the first specimen, that obtained by Sir W. E. Logan, the whole trunk appears to be well preserved, with the exception of the medullary rays.

### 4. Poacites, Knorria (fig. 5), Carbonized Wood (fig. 6), etc.

In addition to the plants above described, the Gaspé sections contain, especially in the beds near the coal-seam, abundance of what seem to be long parallel-sided leaves, with delicate longitudinal striæ, and varying from a fourth of an inch to an inch in breadth. They may be placed provisionally in the genus *Poacites*, but are perhaps leaves of *Nœggerathia*.

Fig. 5 *a*.

Fig. 5 *b*.

Fig. 5. *Knorria*? *a*, nat. size; *b*, magnified.

There is also in the Collection of the Geological Survey of Canada a remarkable fragment, covered with sharp, flat, angular scales. Were it not for its carbonaceous character, I should be inclined to regard it as of animal rather than vegetable origin. If a plant, it must, I presume, be referred to the genus *Knorria* (see fig. 5). In the same collection is a flattened and obscurely marked stem, from rocks of the same age at Kettle Point, Lake Huron. Its markings are scarcely sufficiently distinct for description, but cannot be distinguished from those of some of the varieties of *Knorria imbricata*. Another suite of specimens in the Museum of the Geological Survey indicates the existence of a large plant, the precise nature of which it is perhaps at present impossible to determine.

One of the specimens from Gaspé has the aspect of a long flattened trunk, having in a few places the remains of a carbonaceous coating, presenting longitudinal ribs like those of *Calamites*. It is crossed at intervals by markings not quite at right angles to the sides of the stem, each of which consists of a sharp ridge with a furrow at either side. The specimen is four inches in breadth and about four feet in length. Other specimens from Kettle Point vary from five inches to one inch in breadth; and some of them show traces of longitudinal ribs, but others are quite smooth, or marked only by the rhombic structure-lines of the coaly matter. All show transverse or diagonal ridges, though some of these seem to be merely cracks filled with mineral matter. Crushed Calamites, in a very bad state of preservation, might assume these appearances; but, until better specimens occur, the true nature of these plants must remain doubtful. They are very possibly of the same nature with the Calamite-like stems described by Miller in his 'Testimony of the Rocks,' p. 439.

In every part of the Gaspé sections, beds occur having their surfaces thickly covered with fragments of carbonized vegetable matter, evidently drifted by the currents which deposited the sand composing the beds. A large proportion of these comminuted plants belong to the genus *Psilophyton*; but many are fragments of the wood of larger vegetables. Nearly all are in a very imperfect state of preservation; and most of those that retain their structure show a scalariform tissue similar to that represented in fig. 6, and probably belong to the axis of *Lepidodendron*. Others exhibit elongated woody cells, without minute markings, perhaps from the cortical portion of the same genus, or possibly coniferous*. Another form of carbonaceous matter, abundant in some of the sandstones, consists of scaly fragments resembling the remains of decayed cones, probably *Lepidostrobi*.

Fig. 6.

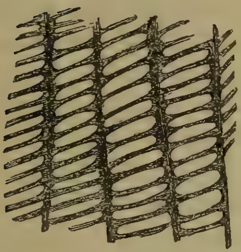

Fig. 6. Scalariform tissue (magnified 300 diams.).

The great abundance of vegetable fragments throughout an immense thickness of rock indicates the existence of extensive land-surfaces clothed with vegetation, though this apparently consisted of but a few species. The small bed of coal occurring in the lower part of the section is composed entirely of irregularly laminated shining coaly matter without mineral charcoal. From its appearance and the vegetable remains in its underclay, I infer that it consists principally of the accumulated rhizomata of *Psilophyton in situ*. Its roof-shale is filled with the Poacites-like leaves before mentioned, and with stems of *Psilophyton*; and it is remarkable that these last are in great part coiled up in the state of vernation, as if overwhelmed by a succession of spring-floods.

### 5. Animal Remains, Rain-marks, etc.

The animal remains found in the plant-beds were *Entomostraca* (*Beyrichia*), *Spirorbis* (resembling that of the coal-measures), Worm-tracks, and Ichthyodorulites (*Onchus* and *Machæracanthus*†). In one of the beds above the coal Sir W. E. Logan found a few brachiopodous shells, apparently identical with those at the base of the series, and also some remarkable transversely marked furrows, which may have been produced by worms or by marine gasteropods.

* *Aporoxylon* (Unger).

† Prof. Newberry regards one of these as identical with his *Machæracanthus sulcatus* from the Devonian of Ohio.

Near the upper part of the section, where the plants become more rare, and the rocks are more abundantly tinged with the red peroxide of iron, the beds are plentifully and often very grotesquely marked with ripple-furrows, shrinkage-cracks, and current-lines. In one or two beds there are surfaces covered with rounded projections resembling casts of rain-marks; and in proof that this is their true character, the surface being irregular, we have not only the rain-marks themselves, but the little rills formed by the gathering drops as they rolled along in this, one of the most ancient showers of which we have as yet any geological record.

The general character of the conditions indicated by the Devonian rocks and flora of Gaspé does not differ materially from that of the Carboniferous period, though the vegetation would appear to have been poorer in species and more exclusively Lycopodiaceous; in which respects it more nearly resembles that of the Lower than of the Middle or Upper Coal-measures. The general history is that of a sea-bottom elevated or filled up in such a manner as to afford sandy or muddy flats, on portions of which plants grew, and on other portions vegetable fragments were drifted, or bare surfaces were exposed to the alternate influences of aqueous deposition and aërial desiccation,—these various conditions being more or less prevalent throughout a long period, during which the area may have been gradually sinking, to be again disturbed and elevated at the commencement of the Carboniferous period.

In explanation of the siliceous and plant-bearing character of the Gaspé beds, as compared with their more calcareous and marine character in some other parts of America, I may point to their vicinity to the old Laurentian land on the north side of the Gulf of St. Lawrence, and to the possible existence of a nearer belt of Lower Silurian land, indicated by the unconformability, in this part of Canada, of the Lower and Upper Silurian rocks.

In the collection of Sir W. E. Logan there are some vegetable remains from the limestones of Cape Gaspé and its vicinity, which perhaps indicate a still older terrestrial flora than that above described. They afford, I think, evidence of the existence of at least one species of *Psilophyton* and one of *Nœggerathia* or *Poacites*; but whether identical or not with those above described, I cannot determine from the specimens. The beds in which they occur certainly underlie the Gaspé sandstones, and are probably Upper Silurian.

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## 2. *On some Points in* Chemical Geology. By T. Sterry Hunt, Esq., of the Geological Commission of Canada.

[Communicated by Prof. A. C. Ramsay, F.R.S., F.G.S.]

§ I. In a paper read before the American Association at Montreal in August 1857, as also in some previous communications to the Royal Society, and in the 'Report of the Geological Survey of

Canada' for 1856, I have endeavoured to explain the theory of the transformation of sedimentary deposits into crystalline rocks. In considering this process we must commence by distinguishing between the local metamorphism which sometimes appears in the vicinity of traps and granites and that normal metamorphism which extends over wide areas and is apparently unconnected with the presence of intrusive rocks. In the former case, however, we find that the metamorphic influence of intrusive rocks is by no means constant, showing that their heat is not the sole agent in alteration, while in the latter case different strata are often found affected in very different degrees; so that fossiliferous beds but little altered are sometimes found beneath crystalline schists, or even intercalated with them.

We cannot admit that the alteration of the sedimentary rocks has been effected by a great elevation of temperature, approaching, as many have imagined, to that of igneous fusion; for we find unoxidized carbon in the form of graphite both in crystalline limestone and in beds of magnetic iron-ore; and it is well known that these substances, and even the vapour of water, oxidize graphite at a red heat, with formation of carbonic acid or carbonic oxide. I have, however, shown that solutions of alkaline carbonates in presence of silica and earthy carbonates slowly give rise to silicates, with disengagement of carbonic acid, even at a temperature of 212° Fahr.,—the alkali being converted into a silicate, which is then decomposed by the earthy carbonate, regenerating the alkaline salt which serves as an intermedium between the silica and the earthy base. I have thus endeavoured to explain the production of the various silicates of lime, magnesia, and oxide of iron so abundant in crystalline rocks, and, with the intervention of the argillaceous element, the formation of chlorite, garnet, and epidote*. I called attention to the constant presence of small portions of alkalies in insoluble combination in these silicates, both natural and artificial—a fact which had already led Kuhlmann to conclude that alkaline silicates have played an important part in the formation of many minerals; and I suggested † that, by combining with alkalies, clays might yield felspars and micas, which are constantly associated in the rocks with the silicates above mentioned. This suggestion has since been verified by Daubrée ‡, who has succeeded in producing felspar by heating together for some weeks mixtures of kaolin and alkaline silicates in the presence of water to 400° C.

The problem of the generation, from the sands, clays, and earthy carbonates of sedimentary deposits, of the various siliceous minerals which make up the crystalline rocks may now be regarded as solved; and we find the agent of the process in water holding in solution alkaline carbonates and silicates, acting upon the heated strata. These alkaline salts are constantly produced by the slow decomposi-

* Proceedings of the Royal Society, May 7, 1857.
† Report Geol. Surv. Canada, 1856, p. 479.
‡ Bull. de la Soc. Géol. de France, 2 série, vol. xv. p. 103.

tion of felspathic sediments, and are met with alike in the waters of the unaltered Silurian schists of Canada and of the secondary strata of the basins of London and Paris. In the purer limestones, however, the felspathic or alkaliferous elements are wanting; and these strata often contain soluble salts of lime or magnesia. These would neutralize the alkaline salts which, infiltrating from adjacent strata, would otherwise affect the transformation of the foreign matters present in the limestone into crystalline silicates. By a similar process these calcareous or magnesian salts, penetrating the adjoining strata, would retard or prevent the alteration of these latter. These considerations will serve to explain the anomalies presented by the comparatively unaltered condition of some portions of the strata in metamorphic regions *.

§ II. As the history of the crystalline rocks becomes better known, we find that many which were formerly regarded as exclusively of plutonic origin are also represented among altered sedimentary strata. Crystalline aggregates of quartz and felspar with mica offer transitions from mica-schist through gneiss to stratified granites, while the pyroxenic and hornblendic rocks of the altered Silurian strata of Canada pass, by admixtures of anorthic felspars, into stratified diorites and greenstones. In like manner the interstratified serpentines of these regions are undoubtedly indigenous rocks, resulting from the alteration of silico-magnesian sediments, although the attitude of the serpentines in many countries has caused them to be ranked with granites and traps, as intrusive rocks. Even the crystalline limestones of the Laurentian series, holding graphite and pyroxene, are occasionally found enveloping broken beds of quartzite, or injected among the fissures in adjacent siliceous strata. From similar facts, observers in other regions have been led to assign a plutonic origin to certain crystalline limestones. We are thus brought to the conclusion that metamorphic rocks, such as granite, diorite, dolerite, serpentine, and limestone, may, under certain conditions, appear as intrusive. The pasty or semifluid state which these rocks must have assumed at the time of their displacement is illustrated by the observations of Daubrée upon the swelling up of glass and obsidian, and the development of crystals in their mass, under the action of heated water, indicating a considerable

* De Senarmont[1], in his researches on the artificial formation of the minerals of metalliferous veins by the moist way, has shown that, by aid of heated solutions of alkaline bicarbonates and sulphurets, under pressure at 200° or 300° C., we may obtain in a crystalline form many native metals, sulphurets, and sulph-arseniates, besides quartz, fluor-spar, and sulphate of barytes.

Daubrée[2] has since shown that a solution of a basic alkaline silicate deposits a large portion of its silica in the form of crystalline quartz when heated to 400° C. We have here, beyond a doubt, a key to the true theory of metalliferous veins. The heated alkaline solutions, which are at the same time the agents of metamorphism, dissolve from the sediments the metallic elements which they contain disseminated, and subsequently deposit them with quartz and the various spars in the fissures of the rock.

[1] Ann. de Chim. et de Phys. 3 série, vol. xxxii. p. 129.
[2] Bull. de la Soc. Géol. de France, 2 série, vol. xv. p. 99.

degree of mobility among the particles. The theory of igneo-aqueous fusion applied to granites by Poulett Scrope and Scheerer, and supported by Elie de Beaumont and by the late microscopic observations of Sorby, should evidently be extended to other intrusive rocks; for we regard the latter as being in all cases altered and displaced sediments.

§ III. The silico-aluminous rocks of plutonic and volcanic origin are naturally divided into two great groups. The one is represented by the granites, trachytes, and obsidians, and is distinguished by containing an excess of silica, a predominance of potash, and only small portions of soda, lime, magnesia, and oxide of iron. In the other group silica is less abundant, and silicates of lime, magnesia, and iron predominate, together with anorthic felspars, containing soda and but little potash. To account for the existence of these two types of plutonic rocks, Prof. J. Phillips supposes the fluid mass beneath the earth's crust to have spontaneously separated into a lighter, siliceous, and less fusible layer, overlying a stratum of denser basic silicates. In this way he explains the origin of the supposed granitic substratum, of the existence of which, however, the study of the oldest rocks affords no evidence. From these two layers, occasionally modified by admixtures, and by partial separation by crystallization and eliquation, Prof. Phillips suggests that we may derive the different igneous rocks. Bunsen and Durocher have adopted, with some modifications, this view; and the former has even endeavoured to calculate the composition of the normal trachytic and pyroxenic magmat (as he designates the two supposed zones of fluid matter underlying the earth's crust), and then seeks, from the proportion of silica in any intermediate rock, to deduce the quantities of alkalies, lime, magnesia, and iron which this should contain.

So long as the trachytic rocks are composed essentially of orthoclase and quartz, and the basic rocks of pyroxene and labradorite, or a felspar approaching it in composition, it is evident that the calculations of Bunsen will to a certain extent hold good; but in the analyses, by Dr. Streng, of the volcanic rocks of Hungary and Armenia, we often find that the actual proportions of alkalies, lime, and magnesia vary considerably from those deduced from calculation. This will necessarily follow when felspars like albite or anorthite replace the labradorite in pyroxenic rocks. The phonolites are moreover highly basic rocks, which contain but very small amounts of lime, magnesia, or iron, being essentially mixtures of orthoclase with hydrous silicates of alumina and alkalies.

§ IV. In a recent inquiry into the probable chemical conditions of a cooling globe like our earth, I have endeavoured to show that in the primitive crust all the alkalies, lime, and magnesia must have existed in combination with silica and alumina, forming a mixture which perhaps resembled dolerites, while the very dense atmosphere would contain, in the form of acid gases, all the carbon, chlorine, and sulphur, with an excess of oxygen, nitrogen, and watery vapour. The first action of a hot acid rain, falling upon the yet uncooled crust, would give rise to chlorides and sulphates with separation of silica; and the accumulation of the atmospheric waters would form a sea charged with salts of soda, lime, and magnesia. The subsequent decomposition of the exposed portions of the crust, under the influence of water and carbonic acid, would transform the felspathic portions into a silicate of alumina (clay) on the one hand and alkaline bicarbonates on the other; these, decomposing the lime-salts of the sea, would give rise to alkaline chlorides and bicarbonate of lime—the latter to be separated by precipitation or by organic agency as limestone. In this way we may form an idea of the generation, from a primitive homogeneous mass, of the siliceous, calcareous, and argillaceous elements which make up the earth's crust, while the source of the vast amount of carbonate of lime in nature is also explained.

When we examine the waters charged with saline matters which impregnate the great mass of calcareous strata constituting in Canada the base of the Silurian system, we find that only about one-half of the chlorine is combined with soda; the remainder exists as chlorides of calcium and magnesium—the former predominating, while sulphates are present only in small amount. If now we compare this composition, which may be regarded as representing that of the palæozoic sea, with that of the modern ocean, we find that the chloride of calcium has been in great part replaced by common salt, —a process involving the intervention of carbonate of soda and the formation of carbonate of lime. The amount of magnesia in the sea, although diminished by the formation of dolomites and magnesite, is now many times greater than that of the lime; for, so long as chloride of calcium remains in the water, the magnesian salts are not precipitated by bicarbonate of soda*.

When we consider that the vast amount of argillaceous sediment-matter in the earth's strata has doubtlessly been formed by the same process which is now going on, viz. the decomposition of felspathic minerals, it is evident that we can scarcely exaggerate the importance of the part which the alkaline carbonates, formed in this process, must have played in the chemistry of the seas. We have only to recall waters like Lake Van, the natron-lakes of Egypt, Hungary, and many other regions, the great amounts of carbonate of soda furnished by springs like those of Carlsbad and Vichy, or contained in the waters of the Loire, the Ottawa, and probably many other rivers that flow from regions of crystalline rocks, to remind us that the same process of decomposition of alkaliferous silicates is still going on.

§ V. A striking and important fact in the history of the sea, and of all alkaline and saline waters, is the small proportion of potash-salts which they contain. Soda is pre-eminently the soluble alkali, while the potash in the earth's crust is locked up in the form of insoluble orthoclase: the soda-felspars readily undergo decomposition. Hence we find, in the analyses of clays and argillites, that, of the alkalies which these rocks still retain, the potash almost always predominates

* See Report Geol. Surv. Canada, 1857, pp. 212–214.

greatly over the soda. At the same time these sediments contain silica in excess, and but small portions of lime and magnesia. These conditions are readily explained when we consider the nature of the soluble matters found in the mineral waters which issue from these argillaceous rocks. I have elsewhere shown that, setting aside the waters charged with soluble lime- and magnesia-salts, issuing from limestones and from gypsiferous and saliferous formations, the springs of argillaceous strata are marked by the predominance of bicarbonate of soda, often with portions of silicate and borate, besides bicarbonates of lime and magnesia, and occasionally of iron. The atmospheric waters filtering through these strata remove their soda, lime, and magnesia, leaving behind the silica, alumina, and potash—the elements of granitic and trachytic rocks. The more sandy clays and argillites being most permeable, the action of the infiltrating water will be more or less complete; while finer and more compact clays and marls, resisting the penetration of this liquid, will retain their soda, lime, and magnesia, and, by their subsequent alteration, will give rise to basic felspars containing lime and soda, and, if lime and magnesia predominate, to hornblende or pyroxene.

The presence or absence of iron in sediments demands special consideration, since its elimination requires the interposition of organic matters, which, by reducing the peroxide to the condition of protoxide, render it soluble in water, either as a bicarbonate or combined with some organic acid. This action of waters holding organic matter upon sediments containing iron-oxide has been described by Bischoff and many other writers, particularly by Dr. J. W. Dawson* in a paper on the colouring matters of some sedimentary rocks, and is applicable to all cases where iron has been removed from certain strata and accumulated in others. This is seen in the fire-clays and iron-stones of the coal-measures, and in the white clays associated with great beds of green sand (essentially a silicate of iron) in the cretaceous series of New Jersey. Similar alternations of white felspathic beds with others of iron-ore occur in the altered Silurian rocks of Canada, and, on a still more remarkable scale, in those of the Laurentian series. We may probably look upon the formation of beds of iron-ore as in all cases due to the intervention of organic matters, so that its presence, not less than that of graphite, affords evidence of the existence of organic life at the time of the deposition of these old crystalline rocks.

The agency of sulphuric and muriatic acids, from volcanic and other sources, is not, however, to be excluded in the solution of oxide of iron and other metallic oxides. The oxidation of pyrites, moreover, gives rise to solutions of iron- and alumina-salts, the subsequent decomposition of which by alkaline or earthy carbonates will yield oxide of iron and alumina: the absence of the latter element serves to characterize the iron-ores of organic origin. In this way the deposits of emery, which is a mixture of crystallized alumina with oxide of iron, have doubtless been formed.

Waters deficient in organic matters may remove soda, lime, and

* Quart. Journ. Geol. Soc. vol. v. p. 25.

magnesia from sediments, and leave the granitic elements intermingled with oxide of iron; while, on the other hand, by the admixture of organic materials, the whole of the iron may be removed from strata which will still retain the lime and soda necessary for the formation of basic felspars. The fact that bicarbonate of magnesia is much more soluble than bicarbonate of lime, is also to be taken into account in considering these reactions.

The study of the chemistry of mineral waters, in connexion with that of sedimentary rocks, shows us that the result of processes continually going on in nature is to divide the silico-argillaceous rocks into two great classes,—the one characterized by an excess of silica, by the predominance of potash, and by the small amounts of lime, magnesia, and soda, and represented by the granites and trachytes, while in the other class silica and potash are less abundant, and soda, lime, and magnesia prevail, giving rise to triclinic felspars and pyroxenes. The metamorphism and displacement of sediments may thus enable us to explain the origin of the different varieties of plutonic rocks without calling to our aid the ejections of the central fire.

§ VI. The most ancient sediments, like those of modern times, were doubtlessly composed of sands, clays, and limestones, although, from the principles already defined in § IV. and § V., it is evident that the chemical composition of these sediments in different geologic periods must have been gradually changing. It is from a too hasty generalization that an eminent geologist has concluded that limestones were rare in earlier times; for in Canada the Laurentian system—an immense series of stratified crystalline rocks which underlie unconformably both the Silurian and the old Cambrian or Huronian systems—contains a limestone-formation (interstratified with dolomites), the thickness of which Sir W. E. Logan has estimated at not less than 1000 feet. Associated with this, besides great volumes of quartzite and gneiss, there is a formation, of vast but unknown thickness, the predominant element of which is a triclinic felspar, varying in composition between anorthite and andesine, and containing lime and much soda, with but a small proportion of potash. These felspars are often mixed with hypersthene or pyroxene; but great masses of the rock are sometimes nearly pure felspar. These felspathic rocks, as well as the limestones, are associated with beds of hematitic and magnetic iron-ores, the latter often mixed with graphite. Ancient as are these Laurentian rocks, we have no reason to suppose that they mark the commencement of sedimentary deposits: they were doubtlessly derived from the ruins of other rocks in which the proportion of soda was still greater; and the detritus of these Laurentian felspars, making up our palæozoic strata, is now the source of alkaline waters by which the soda of the silicates, rendered soluble, is carried down to the sea in the form of carbonate to be transformed into chloride of sodium. The lime of the felspars being at the same time removed as carbonate, these sedimentary strata in the course of ages become less basic, poorer in soda and lime, and comparatively richer in alumina, silica, and potash. Hence in more recent crystalline rocks we find a less extensive development of soda-felspars, while orthoclase and mica, chlorite and epidote, and silicates of alumina, like chiastolite, kyanite, and staurotide, which contain but little or no alkali, and are rare in the older rocks, become abundant *.

The decomposition of the rocks is more slow now than formerly, because soda-silicates are less abundant, and because the proportion of carbonic acid in the air (an efficient agent in these changes) has been diminished by the formation of limestones and coal. It will be evident that the principles above laid down are only applicable to the study of rocks in great masses, and refer to the predominance of certain mineral species at certain geologic epochs, since local and exceptional causes may reproduce in different epochs the conditions which belong to other periods.

§ VII. Mr. Babbage † has shown that the horizons or surfaces of equal temperature in the earth's crust must rise and fall, as a consequence of the accumulation of sediment in some parts and its removal from others, producing thereby expansion and contraction in the materials of the crust, and thus giving rise to gradual and wide-spread vertical movements. Sir John Herschel ‡ subsequently showed that, as a result of the internal heat thus retained by accumulated strata, sediments deeply enough buried will become crystallized and ultimately raised with their included water to the melting point. From the chemical reactions at this elevated temperature, gases and vapours will be evolved, and earthquakes and volcanic eruptions will result. At the same time the disturbance of the equilibrium of pressure consequent upon the transfer of sediment, while the yielding surface reposes upon a mass of matter partly liquid and partly solid, will enable us to explain the phenomena of elevation and subsidence.

According, then, to Sir J. Herschel's view, all volcanic phenomena have their source in sedimentary deposits; and this ingenious hypothesis, which is a necessary consequence of a high central temperature, explains in a most satisfactory manner the dynamical phenomena of volcanos, and many other obscure points in their history, as, for instance, the independent action of adjacent volcanic vents, and the varying nature of their ejected products. Not only are the lavas of different volcanos very unlike, but those of the same crater vary at different times; the same is true of the gaseous matters, hydrochloric, hydrosulphuric, and carbonic acids. As the ascending heat penetrates saliferous strata, we shall have hydrochloric acid, from the decomposition of sea-salt by silica in the presence of water; while gypsum and other sulphates, by a similar reaction, would lose their sulphur in the form of sulphuric acid and oxygen. The intervention of organic matters, either by direct contact, or by giving rise to reducing gases, would convert the sulphates

* Corundum and diaspore are probably derived from basic aluminous silicates like schröterite and collyrite, themselves the kaolin of basic felspars.

† "On the Temple of Serapis," Proc. Geol. Soc. vol. ii. p. 73.

‡ Ibid. vol. ii. pp. 548 & 596.

into sulphurets, which would yield sulphuretted hydrogen when decomposed by water and silica or carbonic acid, the latter being the result of the action of silica upon earthy carbonates. We conceive the ammonia so often found among the products of volcanos to be evolved from the heated strata, where it exists in part as ready-formed ammonia (which is absorbed from air and water, and pertinaciously retained by argillaceous sediments), and is in part formed by the action of heat upon azotized organic matter present in these strata, as already maintained by Bischoff*. Nor can we hesitate to accept this author's theory of the formation of boracic acid from the decomposition of borates by heat and aqueous vapour†.

The almost constant presence of remains of infusorial animals in volcanic products, as observed by Ehrenberg, is evidence of the interposition of fossiliferous rocks in volcanic phenomena.

The metamorphism of sediments *in situ*, their displacement in a pasty condition from igneo-aqueous fusion as plutonic rocks, and their ejection as lavas with attendant gases and vapours are, then, all results of the same cause, and depend upon the differences in the chemical composition of the sediments, temperature, and the depth to which they are buried; and the unstratified nucleus of the earth, which is doubtless anhydrous, and, according to the calculations of Messrs. Hopkins and Hennessy, probably solid to a great depth, intervenes in the phenomena under consideration only as a source of heat.

§ VIII. The volcanic phenomena of the present day appear, so far as I am aware, to be confined to regions covered by the more recent secondary and tertiary deposits, beneath which we may suppose the central heat to be still ascending, a process which has long since ceased in the palæozoic regions. Both normal metamorphism and volcanic action are generally connected with elevations and foldings of the earth's crust, all of which phenomena we conceive to have a common cause, and to depend upon the accumulation of sediments and the subsidence consequent thereon, as maintained by Mr. James Hall in his theory of mountains. The mechanical deposits of great thickness are made up of coarse and heavy sediments, and by their alteration yield hard and resisting rocks; so that subsequent elevation and denudation will expose these contorted and altered strata in the form of mountain-chains. Thus the Appalachians of North America mark the direction and extent of the great accumulation of sediments by the oceanic currents during the whole palæozoic period; and, the upper portions having been removed by subsequent denudation, we find the inferior members of the series transformed into crystalline stratified rocks.

* Lehrbuch der Geologie, vol. ii. pp. 115–122.
† Ibid. vol. i. p. 669.

JANUARY 19, 1859.

John Cavafy, Esq., Westbourne Terrace; William Whitaker, B.A. Lond., Geol. Survey of Great Britain; and T. W. Atkinson, Esq., Old Brompton, were elected Fellows.

The following communications were read:—

## 1. *On the* GOLD-FIELDS *of* BALLAARAT *and* CRESWICK CREEK. By H. ROSALES, Esq.

(In a letter* to W. W. Smyth, Esq., Sec. G.S.)

[PLATE XV.]

I AM not in a position to give any data concerning zoological fossil remains in the auriferous deposits, but I have seen the bottom of the lava entangling not mere stems, but trunks of trees, which I believe to be of the same class as those which still grow in this continent. These were found in the "Eldorado" and "United Miners' Claims" at a depth of upwards of 300 feet below the surface. These "claims" are situated on the "Sebastopol charriage†." Again, another, and perhaps one of the most interesting organic remains, is the cone‡ of a "She-Oak" (*Casuarina*), perfectly charred and interwoven with white pyrites, which was found, along with charred trunks of trees and other vegetable matter, by my friend Mr. Benitua on the "Black-clay Lead," which is the deep auriferous channel at Creswick, where the deposit is reached at the depth of 70–90 feet, and runs under the basalt. In the deep "leads" of Ballaarat large trunks of trees and other charred vegetable matter are constantly to be found; in fact this is characteristic of all the channels as soon as they run into deep ground.

All this leads me to conclude, as you say in your letter, "that the auriferous alluvium is a most interesting subject to link early

* Dated Ballaarat, Sept. 13, 1858.

† The first-found stem entangled in the basalt was met with at the junction of the "Frenchman's" and "White Horse" Leads in the "Eldorado" Claim, at 305 feet from the surface. It was still firmly rooted in the slate, surrounded up to the height of 8 feet by the alluvium of the auriferous channel, and then entangled in the oldest basalt-flow yet known (the "4th rock" in miner's parlance), to an unknown height. The basalt is amygdaloidal (honey-combed), of a dark-greyish colour, and rests on the alluvial deposits and on the schists, which at the contact are broken up into a breccia; between both rocks there is a thin layer, from 3 to 6 inches thick, of black clay, containing more or less charred matter. I could not ascertain what influence the basalt had had in its contact with the alluvial deposit. At the point referred to, the course of the "Frenchman's Lead" is N. 30° W., that of the "White Horse Lead" W. 9° S., and after the junction the course of the "Sebastopol" auriferous mainchannel is W. 17° N. The trunk of the tree is 3 feet in diameter in the direction of the "White Horse," 2½ feet in that of "Frenchman's" Lead, and is perfectly preserved in a charred state. In the claim of the "United Miners" there are two more trunks; one also perfectly preserved, but the other, which when found contained a quantity of white pyrites, is now completely destroyed; however in the basalt there still remains the cylindrical vacuum, where there was once a tree. The "United Miners'" Claim is 345 feet deep in the gutter at the lower end of the claim.

‡ See also Quart. Journ. Geol. Soc. vol. xiv. p. 541.—EDIT.

geological epochs to an historic period . . ., establishing such a curious analogy with the gold-washings of Siberia and their Mammoth bones, and the Cornish stream-works with the bones of the great Irish Elk, &c.," and to believe that the geological parallelism of this and the Siberian auriferous alluvium will be established; but I regret to say that I fear it will prove rather difficult, inasmuch as the miners do not feel interested in the like pursuits, and naturally overlook, destroy, or cast away those samples and specimens which science so highly covets.

I intend endeavouring to give you in this letter a clear idea of the geological features of this district: namely, its petrographical structure; the situs of quartz-lodes and veins (the matrix of gold) in schists on the Ranges, from whence arise auriferous gullies, forming eventually several auriferous channels (charriages); and finally also the different courses of streams and successive auriferous channels, which latter, gradually dipping, attain the Basalt, under which they continue their hidden course.

By carefully perusing the geological map (Pl. XV.) and the accompanying references (pp. 502-3), which I have been at great pains in making (having had to walk over many and many a mile, sometimes under a scorching sun and sometimes in the cold and wet), you can see at a glance the truly simple geological structure and history of this "Gold-field" *par excellence.*

Now that you have gone over the map, the references, and Synopsis, will you take a walk with me over the field? It will not tire you; for I shall at once repair to the highest point on the Redhill Range (40), from whence you have such an extensive view and so interesting a geological panorama, that I named the spot "Panorama Point."

The Redhill Range extends several miles south, dividing the auriferous gullies in east and west currents, and is the corresponding bluff of the Blackhill Range (21), which continues in a northerly direction, also dividing the auriferous gullies into E. and W. currents, until it reaches the Dividing Range. The large gap between both bluffs was formed by the destructive influence of the currents when forcing their way through the ridge.

Before us then, to the north, is the Black Hill (21), with its quartz-lodes and -veins cropping out; and we stand on the opposite bluff, the Red Hill, where the Golden Point (36) and other quartz-reefs also crop out near its summit. To the N.E. is the Brownhill Range crowned by the Monte-Christo quartz-reef (8), and it was between the Blackhill and the Brownhill Ranges that the Eureka Channel (13) once rolled its really auriferous sands.

Below us, as already referred to, is the wide gap, the present flat, and at the depth of 200 feet was found the auriferous mainchannel, the Gravel Pits (25), into which ran the aggregate and different channels of Eureka, Canadian (58), and Manpoke (22).

Almost due E. is the cone of the extinct volcano Mount Warrenheep, towards which extends the auriferous alluvial deposit, limited in that direction by schist-ranges; the same which you observe to the S.E., where the conical elevation in the background is Mount Buninyong, also an extinct volcano*.

You can also distinguish from this point the course of the shallow channel, coming from the E.S.E. Ranges to Pennyweight Hill and Pennyweight Flat (34), where, crossing over the course of a deep auriferous channel (the Canadian), it was afterwards washed away by the present Canadian Creek, and is found on the opposite side on Poverty Point (35), pursuing its course to Golden Point (36), the White Flat (37), and Balaclava (I), where it has been found under the basalt in two or three pits; and, although not searched for any further (on account of the poorness of the "stuff," as the miners say), some time or other its course will be disclosed. There is another most interesting spot (46), where again successive channels are to be observed. It is at the lower end of the White Flat; here the shallow auriferous channel covers a deep auriferous lead, and the River Yarrowee or Leigh flows over the former†. Another instance would in all probability be found at Creswick, where I understand that the shallow channel in Portuguese Flat covers the deep one; and, although I have repeatedly heard that a "false bottom‡ was gone through," still, as I have not inspected the place, I cannot say more about it (see P.S.).

Thus again the successive periods of deep and shallow channels would seem to be almost satisfactorily established; but there must be many more, for what are the drifts above the lower deposits of the deep channels? The study of the successive periods of channels is a most interesting one, but somewhat intricate§.

Continuing our observations, you see the township of Ballaarat to the N.W., built on the basalt-bluffs. Turn now more westward, and you discern the great extent of ground covered by basalt, which igneous rock filled up the channels, valleys, and plains of the *then* low ground, extending in all probability under the Lakes Burrembeet and Laermonth towards the granite-ranges, the Pyrenees, pursuing its gradual fall then in a direction perhaps W. of the extinct volcanos Mount Emu and Mount Elephant.

Thus the basalt has thrown a trappean veil over the ante-volcanic plains; raise this veil for a moment, and then you would discover unknown schist-ranges, unknown channels and plains, and the re-

* It was from Panorama Point and from the Black Hill that, some years ago, I made a summary survey of the levels of the alluvium, ranges, &c. of the ground situated to the E. and S.E. of Panorama Point, and was enabled to conclude, as I then stated (Quart. Journ. Geol. Soc. vol. xi. p. 398), that the Eureka would run into the mainchannel somewhere about Pennyweight Flat (34). This has since eventually happened, although, at the time I made the hypothesis and prognosis, the Eureka had only been traced just to the S. side of the Yarrowee.

† At this spot the shallow channel was struck at the depth of 15 feet below the River Yarrowee, which flows in a S.S.W. direction; the auriferous drift and the quartz-boulders were lying on a "false bottom," sinking through which, to 45 feet more depth, in clayish alluvium, was sufficient to reach the gutter of the Nightingale Lead (45) bearing W.N.W., on the "true bottom," the schists.

‡ For this term, see my first letter, Quart. Journ. Geol. Soc. vol. xi. p. 397.

§ See notes by Mr. Phillips and Mr. Rosales on this subject in the Quart. Journ. Geol. Soc. vol. xiv. pp. 538 and 543.—Edit.

mains of a vegetation, and perhaps of animals, similar to those at present in this continent. But this "terra incognita" will only be disclosed, and we may say conquered from the Kobold phantom, by persevering mining and industrial appliances.

It is under this extensive basalt-formation, partly bounded on the S.W. by the schist-ranges and granite of Smythe's Creek, that the different auriferous mainchannels, the Dead Horse (3), the Golden Point (26), the Sebastopol (73), and Black-clay Leads (84), have entered upon their mysterious course: the miner might say it is a merciless one.

Further to the N. of Dead Horse there are other leads, for instance Northumberland and Sulky-gully Lead; but I have not extended my observations in that direction. It is true that there is not much to observe there; suffice it to say that the named leads are directing their course to westward.

Now that we have had, as it were, unfolded before us the geological habitus of this field, we will ascend Mount Buninyong.

Let us consider how we stand. To the N.W., and divided from us by high schist-ranges, lies Ballaarat; and Mount Warrenheep lies N. Further westward, we again see the lakes, the Pyrenees, and the extensive basalt-plains, the monotonous aspect of which is only now and then relieved by the bold cones of extinct volcanos. At our feet, looking due W., is the township of Buninyong.

From here you see how the Redhill Range (its summit crowned at intervals by the White Horse, Great Republic, and other auriferous quartz-reefs) follows a southerly direction towards the Long-gully (80) and Buninyong Cemetery quartz-lodes, where the range is intercepted. The debris of this part of the range supplied the alluvial deposits which are all united in the Black-clay Mainchannel (84). You also easily distinguish a shallow channel, which seems to arise somewhere E.N.E. of Buninyong, at the S.W. boundary of the township, showing itself again extensively developed on the Chalk-hills (85); at the south end of which (notice it particularly) the schists are again seen to crop out, following the southerly direction of the Redhill Range,—again cropping out between Laermonth's paddock and the River Yarrowee, where, following the same direction, they are again visible at the crossing-place, and finally form the ranges from whence arise the Welshman's (89), Rider's (90), and Durham (91) Leads on the E. side (which Leads eventually will join the Greenhill Mainchannel, 92) and the Napoleon's Lead on the western side, which latter takes even a due N. direction, tending in all probability to join the Black-clay Lead.

Thus the southerly continuation of the Redhill Range is the schist-ridge which divided two great ante-volcanic valleys from each other, and parted the course of the above-mentioned mainchannels (Black-clay, Sebastopol, &c.) from that of the Greenhill auriferous mainchannel (92), which doubtless will keep a southerly course, whilst the other mainchannels pursue at present a westerly direction; and it might figuratively be said that this interesting ridge, which is to be traced from hence along the Redhill and Blackhill

Ranges unto the Dividing Range, is the spinal bone of the frame of this gold-field.

I have purposely avoided saying anything about the "Springs Diggings" (1 & 2), situated far to the N.E. of Ballaarat. It is an interesting locality, but one which I have not sufficiently studied. However there are two distinct successive channels or auriferous "charriages;" those in the gullies, and that which runs under the basalt. In what geological relation they stand to the successive channels of Ballaarat or of Creswick, I am not prepared to say; still I should think "charriage" No. 2 contemporaneous with the shallow channel of Creswick. The course of both "charriages" diverges from this gold-field, and lies in some glen unravelled at present, bearing towards Lal Lal Creek.

I have gathered a few things: some gold-specimens and crystallized gold in the forms D; H, O; O, H; and one crystal D, O, H, and small facettes of Naumann's Hexakistetraëder; also some zeolites and a few vegetable organic remains.

P.S. Since writing the above I have been to Creswick and have obtained correct particulars on the subject from Mr. E. Millner and party, who worked on the ground. On Portuguese Flat, at the depth of about 10 feet, there is an auriferous deposit (1) which spreads mostly over the flat, resting on the schists, but frequently also on a "false bottom." Through this deposit the Creswick Creek has forced its present course, which is very near N. At the depth of 26 feet, another auriferous channel (2) is met with, about 9 feet wide on an average, bearing W. 10° N., resting also partly on schists and partly on a "false bottom." This channel crosses over a deep auriferous channel (3, the Wet Lead) which is found at a depth of 48 feet (22 feet below the No. 2 channel), resting only on the schists, which form the "true bottom;" it is 15 feet wide on an average, and its course is N. 15° W.

Perhaps I may some time or other be enabled to show a certain analogy between the periods of some of the auriferous drifts and the epochs of volcanic eruptions.

### *Synopsis of the Auriferous Gullies, Channels, and Mainchannels.*

Springs Diggings; auriferous gullies and channel, bearing under the Basalt towards Lal Lal, *i. e.* S.E.

*Dead-horse Gullies*; *the channel* now under the Basalt, bearing W., into which will run the Northumberland Lead (?).

Little Bendigo, Nuggety Gully, Kangaroo Gully, several other gullies, Rotten Gully, Brownhill Gully, and Cockatoo Gully, fall into the Eureka Channel, into which subsequently run the Nil desperandum, Caledonian, Lady Berkeley, and Blackhill Leads, forming the

Eureka Mainchannel, which joins the Gravel-pits Mainchannel.

One-eye Gully, Scotchman's Gully, New-chum Gully, Tailors' Gully, Prince Regent Gully, and Canadian Gully form the

Canadian Mainchannel, which, after the confluence of the Warrenheep, Navie Jack's, and the Redhill Leads, would empty into the Gravel-pits Mainchannel.

Pennyweight Flat, Poverty Point, Golden Point, White Flat, and Balaclava show the course of the

Shallow Channel of Ballaarat.

The Mopoke Gullies, and the Bakery-hill Lead form the

Mopoke Mainchannel, which likewise runs into the

Gravel-pits Mainchannel, which just below the Camp enters on its sub-basaltic course, goes under Bath's Hotel, and meets the Golden-point Deep Lead under Dana Street. Here ends the famous Gravel-pits Mainchannel *according to law*; for the Golden-point Lead, having been registered before the Gravel-pits, takes the precedence, and hence it is that after the junction of these two leads the Golden-point Lead retained the name—and so the

Gravel-pits Mainchannel died a *legal* death, although not a geological one. The Golden-point Lead is, we may say, a "*parvenu*"; its course is W.S.W.

The Inkermann Gullies, A 1 Lead, and the Haphazard Lead form the

Inkermann Channel, which, falling fast in a S.S.W. direction, will soon end its golden career, running into the Golden-point Mainchannel. So also will the Nightingale, Malakoff, and Milkmaid Leads, as also the more important Miners' Right and Mount Pleasant, which two form the

Redan Channel, and bearing N.W., run into the

*Golden-point Mainchannel.*

The Woolshed Gullies form the Woolshed Channel, the Terrible Gullies form the Terrible Lead, the White Horse Gullies form the White Horse Lead, and the Frenchman's Gullies and the Magpie form the Frenchman's Lead. The last three leads, after their junction, form the

*Sebastopol Mainchannel,* bearing W.

Into this mainchannel, the united channels of the Raglan, Cobler's, and Long Gully will eventually run.

The Black-lead Gullies, Hiscock's Gullies, Poor-man's Gully, and Sussex form respectively the Black Lead, Hiscock's Lead, Nelson's, and the Sussex Lead, which, joining together, form the

*Black-lead Mainchannel,* bearing W.

The Chalk-hills, the

Shallow channel of Buninyong, is only to be found in unconnected portions. Its course, however, is likely to be detected in a westerly direction.

The Union Jack, Scotchman's, Devonshire, Welshman's, Rider's, and Durham Leads will all join the

*Greenhill Mainchannel,* the course of which bears southward.

### *References to the Numbers and Letters on the Map.* Pl. XV.

1. Auriferous Gullies } Springs Diggings.
2. " Channel } Springs Diggings.
3. Dead-horse Channel.
4. " Quartz-reef.
5. Nuggety Gully.
6. Little Bendigo.
7. Kangaroo Gully.
8. Monte Christo Quartz-reef.
9. Brownhill Gully.
10. Rotten Gully.
11. Hit or Miss Gully.
12. Cockatoo Gully.
13. The Eureka Channel.
14. Brownhill Channel.
15. Caledonian Channel.
16. Long-looked-for Channel.
17. Lady Berkeley Channel.
18. Nil-desperandum Channel (where the N.-desp. nugget was found).
19. Blackhill Channel.
20. Bakery-hill Channel.
21. Blackhill Quartz-lodes and -veins.
22. Manpoke Channel.
23. Junction where the Welcome nugget was found.
24. The lower end of Mopoke Lead.
25. Gravel-pits Mainchannel.
26. Junction of the last and the Golden Point deep Channel.
27. Inkermann Channel.
28. A 1 Channel.
29. Haphazard Channel.
30. Township Quartz-reef: strike N. 11° W.!
31. Great Western Bore } Bores to find the course of Golden-point Mainchannel (26).
32. Band of Hope Bore } Bores to find the course of Golden-point Mainchannel (26).
33. Victoria Bore . . . } Bores to find the course of Golden-point Mainchannel (26).
34. Pennyweight Flat.


Geological plan of the
GOLD-FIELD OF BALLARAT
1858.
To illustrate Mr. H. Rosales's paper.
The Brothers
Mt. Rowan
Creswick
The Tullarook
(Continuation Northward)
DIVIDING RANGE
Swamp
or River Leigh
Ballarat
Mt. Warrenheep
Mag. N.
Green Hill
Mt. Buninyong
Buninyong
The Yarrowee
RANGES
Great Roads.
Creeks and Gullies.
Shallow Auriferous Channels.
Gold-Gullies in the Ranges running to the Basalt.
Course of the deep Channels under the Basalt.
Granite.
Granitic detritus.
Basalt.
Quartz-lodes in the Ranges.
Schists.
General strike of the Quartz-lodes.
Scale ½ an inch to a mile.
0 1 2 3 miles.

J. W. Lowry fc.

35. Poverty Point.
36. Golden Point.
37. White Flat.
I Balaclava.
38. Redhill Line (Channel).
39. Canadian Channel (Dalton's Flat).
40. Panorama Point (Redhill Range).
41. Navie Jack's Channel.
42. Sinclair's Hill.
43. Gay's Rush.
44. Warrenheep Channel.
45. Pit on the Nightingale Channel.
46. Interesting point on the Nightingale Channel.
47. Junction of the last and the Malakoff Lead.
48. The Milkmaid's Channel.
49. The Malakoff Channel.
50. Mount Pleasant Channel.
51. Miners'-right Channel.
J. Redan Channel.
52. Golden-gate Pit . . . .
53. Golden-gate Pit . . . .
54. Red Lion Bore . . . .
55. Perseverance Bore (through 300 ft. of rock)
} Probable course of the Redan.
56. Golden-point or Old Post Office Quartz-reef.
57. Canadian Quartz-reef.
58. Canadian Gully
59. Prince Regent Gully . . . .
60. Sailor's Gully .
} At their junction were the jewellers' shops.
B. Bath's Hotel.
C. The Cosmopolitan Pit . . . . . . .
K. The Kohinoor Pit
A. Atlas Pit . . . . .
} Probable course of the Golden-point Mainchannel.
61. Madman's Flat.
62. New-chum's Channel.
63. Scotchman's Gully.
64. New-chum Gully.
65. One-eye Gully.
66. Woolshed Gullies.
67. Woolshed Channel.
68. Terrible Channel.
69. White Horse Channel.
70. White Horse Quartz-lode or -reef.
71. Frenchman's Channel.
72. Magpie Lead.
73. Sebastopol Mainchannel.
74. Working Miners' Pit . . . . . . .
75. Evening Star Pit
76. Last Pit . . . . .
} Probable course of the Sebastopol Mainchannel.
77. Raglan Channel.
78. Cobler's Channel.
79. Long-gully Channel.
80. Long-gully Quartz-reef.
81. Hiscock's Quartz-reef.
82. Hiscock's Channel.
83. Union Jack's Gully.
84. Black-lead Mainchannel.
85. The Chalk-hills.
86. The Devonshire Channel.
87. The Scotchman's Channel.
88. A patch of shallow Channel.
89. Welshman's Channel.
90. Rider's Channel.
91. Durham Channel.
92. The Greenhill Mainchannel.
93. Poor-man's Gully.
94. Nelson Channel.
95. Sussex Lead.

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## 2. Description *of* Two Species *of* Cephalaspis.

By John Harley, Esq.

[Communicated by Prof. T. Huxley, F.G.S.]

(Abstract*.)

A new form of *Cephalaspis* (*C. Asterolepis*) was found by the author about two years ago at Hopton Gate, about four miles east of Ludlow, in a bed of coarse Old Red conglomerate overlying a compact calcareous sandstone, which latter abounds with fragments of *Cephalaspis Lyellii* and *Pteraspis*, and in its upper part contains remains of *Pterygotus problematicus*? The former is horizontally bedded, and alternates with a brown micaceous shale, in which are carbonized fragments of plants.

*Cephalaspis Asterolepis* from the Old Red Sandstone of the neigh-

* This memoir in full will be incorporated with the descriptions of the *Cephalaspides* in the 'Monographs' to be published by the Geological Survey.

bourhood of Ludlow is by far the largest species that has been discovered, the cephalic plate having at least twice the dimensions of that of *C. Lyellii.* In outline it is broadly semielliptical. In addition to its large size, it is distinguished by the position, obliquity, and magnitude of the orbits. Placed almost entirely on the posterior half of the shield, these diverge from each other so as to be distant 1 inch apart anteriorly, and $\frac{1}{2}$ an inch posteriorly. The long diameter of each orbit measures $1\frac{1}{4}$ inch. Within the orbital circumference remains of the osseous sclerotica are visible. Owing to the backward position of the orbits, it is in the posterior part of the shield that we find some of the chief distinctive modifications: thus the occipital crest is even shorter than that of a species less than half its size; the space between the orbital ridges is proportionately small.

The outer enamel-layer is ornamented with tubercles, which bear so close a resemblance to those covering the bony plates of *Asterolepis* as to have suggested the specific name. They present, however, considerable variation: usually they arise by a circular and more or less tumid base, which gradually terminates in an elevated papilla; or the papilla may be small, rounded, and distinct from the base. Sometimes two or even three minute papillæ surmount the same base; sometimes the base is quite flat and expanded, and is occupied by a solitary central papilla. In all cases the base presents more or less distinctly a radiated striation. The inner layer of the bony plate presents lacunæ and long branching canaliculi precisely resembling those of human bone. Many of these are completely injected with a transparent blood-red material; and so beautifully are they displayed, that one ignorant of the structure of bone would be able to apprehend it by a glance at a minute part of this ancient fragment.

So wonderfully indeed has nature treasured up her secrets in this disentombed relic of a time so distant as to be incalculable, that she distinctly reveals in their minutest details the structure of canals not more than the $\frac{1}{50,000}$th of an inch in diameter, and such as defy the skill of the anatomist to inject.

Mr. Harley also described a more perfect specimen of *Cephalaspis Salweyi* than the one on which Sir P. Egerton not long since determined the species*. It was found by Mr. Salwey at Hinstone near Bromyard, and about $1\frac{1}{2}$ mile from Acton Beauchamp, in a sandstone similar to that in which the other specimen was found at Acton Beauchamp.

*Cephalaspis Salweyi* proves to differ but very little in size and external configuration from *C. Lyellii.* It is distinguished from this species by its short and slender postero-lateral spines, which are not prolonged further backwards than the termination of the occipital crest. The internal parts of the posterior third of the shield form a distinct, arched, nuchal plate, which is prolonged posteriorly. The occipital crest is prominent, and bifurcates anteriorly into the orbital ridges. These, diverging, curve a little outwards and pass to the

* Quart. Journ. Geol. Soc. vol. iii. p. 283.

posterior margins of the orbits, enclosing between them a tabulated surface, which, occupying the central and most elevated parts of the general surface, forms a prominent feature. The orbits are small and slightly oval; they are situated entirely on the *anterior* half of the shield. The enamel-layer forms small, oblong or round, pearly drop-like tubercles, which are numerous and for the most part discrete. The spaces between them are grooved into parallel or slightly divergent ridges, which pass from their sides and ends. The structure of these tubercles is very vascular.

Associated with this fossil, the author found the dermal plate or the tooth of a placoid fish, which has close resemblance to the teeth of *Cestracion* and the Rays, and even closer still with the bone of the Silurian bodies called by Pander *Cœlolepidæ*. It was discovered almost between the jaws of *C. Salweyi*, and thus suggests the paradoxical question—does it belong to that fish?

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FEBRUARY 2, 1859.

Signor Gennaro Placci, Florence, and Zacatecas, Mexico; John Henry Sylvester, Esq., Assist.-Surgeon, Indian Army; and Joseph Frederick Whiteaves, Esq., St. John Street, Oxford, were elected Fellows.

The following communication was read:—

## *On the* MODE *of* FORMATION *of* VOLCANIC CONES *and* CRATERS. By G. POULETT SCROPE, Esq., M.P., F.R.S., F.G.S., &c.

IN a paper read before the Society in April 1856, I called attention to this subject*. I should have thought further recurrence to it unnecessary had it not been that, in the first part of the fourth volume of Baron Humboldt's 'Kosmos' (of which a translation has recently issued from the press, under the superintendence of General Sabine), that distinguished author, while treating very fully of volcanic action, gives the unqualified support of his great authority to the theory of upheaval as contradistinguished from that of eruption in reference to the origin of volcanic cones and craters,—a theory which, in common with Sir Charles Lyell, M. Constant Prévost, and many others, I believe to be not merely erroneous, but destructive of all clearness of apprehension as to the part which volcanic action has really played in the structural arrangement of the earth's surface.

I think I shall be justified in this last observation in the opinion of any person who will peruse with attention Baron Humboldt's work, and endeavour to realize some definite idea of what the author considers volcanic action to be—how cones or craters are formed—how

* Quart. Journ. Geol. Soc. vol. xii. p. 326.

lava-currents conduct themselves when expelled under varying circumstances upon the earth's surface—what volcanic mountains, or what portions of any such, are the product of eruption and accumulation, and what of the mere mechanical upheaval in mass of preexisting beds. The whole subject is rendered indistinct, and I will venture to say unintelligible, by the author's adhesion to the theory of "Cones and Craters of Upheaval," first dogmatically enounced by M. Leopold von Buch, and subsequently supported, with most elaborate—but, as it appears to me, very inconclusive—arguments, by MM. De Beaumont and Dufrénoy. Now, although the study of the laws of volcanic action is a branch of geology which has not attracted much attention in this country, yet every one will, on consideration, admit that, among all the forces of nature which may be seen in activity on the surface of the earth, the volcano is by far the most striking in its phenomena, and the most directly demonstrative of the character and mode of operation of those (as yet little understood) subterranean agencies by which the crust of our globe has been unquestionably from time to time modified, and was in all probability in a large degree elaborated.

It cannot, therefore, but be of paramount importance to the progress of the science, that just and correct views should prevail upon this subject, and that, if erroneous opinions have been promulgated, they should be thoroughly exposed and refuted.

It is true that the able, though succinct, argument against the Upheaval doctrine, contained in the last editions of the 'Principles' and 'Manual' of Sir Charles Lyell, together with the paper recently read by him before the Royal Society, and printed in the 'Philosophical Transactions,' in which he corrects the representations of M. Elie de Beaumont on this point, with respect to the lava-currents of Etna, may be thought to have rendered any other effort of the kind superfluous. I may, however, remark that this, like many other unsound doctrines, when once promulgated by high authority, requires more than one blow to destroy it. In more than one recent elementary work on Geology * the Upheaval theory is still put forward as the true explanation of volcanic action. Our distinguished associate, Dr. Daubeny, to a great extent, advocates it in the last edition of his work on that subject, and has not hitherto changed his opinion, so far as I am aware. Professor James Forbes yet lends it his countenance. The majority of geological schools on the Continent still teach it as a matter not open to controversy. It is, indeed, disheartening to reflect how successfully an erroneous theory of this character may be set up, and how widely and enduringly it may be thenceforward propagated, under the influence of one or two great names—finding its way, as a matter of course, into all popular compilations,—and with what difficulty its refutation can be established.

In the present instance I have myself to repeat arguments which

* *E. g.* in Keith Johnston's 'Physical Geography'; Lardner's 'Geology'; Professor Ansted's 'Elementary Geology'; the article Geology in the 'Encyclopædia Metropolitana,' &c.

more than thirty years ago I addressed to the Society upon the same subject; and, under these circumstances, I hope I shall not be deemed to trespass unnecessarily upon the attention of its members if I now offer to them some further considerations in opposition to what cannot be yet looked on as an exploded fallacy.

I shall avoid repeating, and only briefly allude to, the able arguments with which all are conversant in Sir Charles Lyell's publications, and endeavour to reinforce them by others derived chiefly from my own observations.

But first it will be convenient that I should clearly point out what is the real question in dispute.

In common with the unscientific world, and forming their judgment on the usual character of the observed phenomena of volcanos, all the early geologists who made this department of science their special study—such as Saussure, Spallanzani, Sir W. Hamilton, Dolomieu, Breislak, &c.—were accustomed to consider a volcanic mountain as the result of the *accumulation*, over and around an eruptive vent, of the fragmentary matter and lavas thrown out from it. Where but one eruption had occurred, the result appeared to them to be a conical hill composed of scoriæ, lapilli, or other loose ejecta, usually having a crater at its summit, and a single current of lava, which, after flowing from the summit or flank, or perhaps from the base of the hill, spread over the adjoining surfaces in a sheet or stream, whose dimensions would be determined by the quantity and fluidity of the lava emitted, and by the levels of the surface upon which it was poured out. Where repeated eruptions occurred from the same habitual volcanic vent, the result, it was naturally supposed, would be a proportionately larger and higher cone; a volcanic mountain, in fact, composed (as such mountains are observed to be) of irregularly alternating layers of fragmentary ejecta and lava-streams, sloping outwardly on all sides from the central summit of the volcano, where the vent would be generally marked by a crater.

Thus, to give a single instance, Spallanzani describes the island of Saline, one of the Lipari group, as composed of repeated beds of lava and scoriæ, one above the other, sloping from the summit-edge of the crater to the sea around; and goes on to say, "We must conclude that there were at least as many eruptions from the summit of this mountain as we can count beds of lava. *Thus it is that volcanic mountains are for the most part formed.* In the beginning it is only the *accumulation* of the products of one first eruption; then a second takes place; then a third; and the mass goes on increasing always in bulk in proportion to the number of eruptions. Thus was, no doubt, formed, increased, and extended the colossal bulk of Etna. Such was the origin of Vesuvius, of the Lipari Isles, and of other volcanic mountains,—not, however, forgetting that some minor volcanic hills, like the Monte Nuovo, and the Monte Rosso on the flank of Etna, were produced by a single eruption*."

For this simple and common-sense theory of the mode of forma-

* Spallanzani, 'Voyage dans les Deux Siciles,' ii. p. 116.

tion of volcanic mountains (which I need hardly say I myself adopted and enforced in my 'Considerations on Volcanos,' published in 1825) has been substituted by certain later geologists, chiefly of the Continental schools, one which ascribes the production of all, or nearly all, volcanic mountains to the sudden 'upheaval,' at one shock, of a tract of pre-existing horizontal strata of lava and volcanic conglomerate, into the shape of a hollow cone or dome, inflated like a bladder by the sudden expansion of a great volume of vapour beneath; which bubble or bladder is further supposed to have burst at the top whenever a crater is found there. In order to avoid misrepresentation, I will quote the definition given by Baron Humboldt, the latest exponent (as well as, I believe, the original inventor) of this theory. In the recently published volume of his 'Kosmos*,' he says:—

"In regard to volcanos, the form-giving, or shaping, activity is exerted by the upheaval of the ground; not (as was formerly and almost exclusively believed) in *building up by successive accumulation* of scoriæ and strata of lava deposited over one another. The resistance which the fiery-fluid masses, pressed in too great abundance (from below) against the surface, find at the spot which is to be the channel of eruption, occasions the augmentation of the upheaving force. There arises a '*bubble-shaped pushing-up of the ground*,' as is indicated by the regular outward slope of the *upheaved* strata. A *mine-like explosion*, the bursting of the central and highest portion of this convex swelling of the ground, sometimes produces what Leopold von Buch has termed a 'crater of elevation,'—and, when the structure of a *permanent* volcano is to be completed, a dome-shaped or conical mount likewise, in the middle of the 'crater of elevation,' which inner mount is also, in the greater number of cases, open at its summit," &c.

The first suggestion of this theory is, I believe, to be found in M. de Humboldt's own description of the Mexican volcano of Jorullo, in his great work on New Spain†. In his 'Atlas Géographique,' ed. 1814, he gives also views and plans of the products of the great eruption of 1759 at that locality, which, according to his notion, occasioned the sudden swelling up of the surface of a previously flat plain into an immense hollow convexity in the shape of a blister or bubble, "*en forme de vessie*;" from the midst of which convexity or "*plaine bombée*," locally called the "Malpais," arose six great conical hills, covered with volcanic ashes, the largest of which—the mountain of Jorullo proper—*has a crater*, and a massive promontory of basaltic lava attached to it, and appearing to cascade, as it were, from the crater at a point high up on the flank of the cone. The surface of the convex plain was also studded with thousands of small hillocks under ten feet high, which, at the time of M. de Humboldt's visit in 1780, twenty years after the eruption, were still smoking, and thence called "hornitos," or ovens, by the natives of the country;

* Part I. p. 224. Sabine's Translation, 1858.
† Essai Politique sur la Nouvelle Espagne, ed. 1811, vol. i. p. 251.

appearing to be composed, outwardly at least, of a black indurated clay, or earthy "decomposed basalt" (for M. de Humboldt seems rather doubtful what to call it) having a globular concretionary and concentric lamellar structure; and these small protuberances, as well as the large conical hills, and the entire convexity of the Malpais, are alike considered by him as so many hollow inflated blisters (see figs. 1, 2, and 3). These appearances so explained, he rightly calls, in his recent volume of 'Kosmos,' "The greatest, and, since my American journey, the most celebrated phenomenon of volcanic upheaval." I believe this to have been also the *first* statement ever announced to the world of such a phenomenon, with the exception of that (to which M. de Humboldt is never tired of referring as an authoritative example) in the 'Metamorphoses' of Ovid, who vaguely reports a tradition of something similar having occurred at Methone in Greece *.

While engaged, many years back, upon my work on Volcanos, which was published in 1825, I was so struck with the discordance of M. de Humboldt's theory of the eruption of Jorullo with the then-known ordinary laws of volcanic action, that I was led to institute a close examination of the facts and relations respecting this celebrated event, upon which his view of its origin was grounded. And in the appendix to that work I showed in detail (and I venture to think conclusively) that the theory is not at all warranted by either class of evidence; on the contrary, that both the relation of the phenomena that accompanied the eruption, as given by M. de Humboldt himself from the reports of eye-witnesses, and its results as observed and described by him, are perfectly consistent with the usual course of proceeding of an ordinary volcanic eruption, witnessed in numberless examples in other parts of the globe; that the six conical hills are common eruptive cones of scoriæ, ashes, and other fragmentary matters (of which prodigious quantities are stated in every account to have been thrown up from these several points of the original plain †, at the commencement of the eruption and throughout many subsequent months); that the convexity of the "Malpais" surrounding these cones is (like all the other "Malpais" of Spanish America) but the surface of a thick bed of imperfectly liquid basaltic lava, which, having been poured out of these vents in great abundance upon a flat plain, naturally accumulated there around their base (its greatest height above the original plain being only 470 feet, therefore not thicker than some of the lava-streams of Iceland), and this at the foot of the great cone of Jorullo, from which is yet seen descending into and joining the "Malpais" a very bulky promontory of coarse-grained lava, by which M. de Humboldt climbed up to the crater; finally, that the mysterious, but really insignificant, "hornitos" (which, by the later account of Mr. Burkart, seem to have very soon disappeared, their covering being washed away by the rains) were merely the higher superficial

* "Extentam tumefecit humum, ceu spiritus oris
Tendere vesicam solet."—*Ovid*, 'Met.' lib. xv.

† Jorullo, the largest, is 1200 feet high from the plain.

Fig. 1.—*View of Jorullo and its Malpais.* (From Humboldt's 'Mexico.')

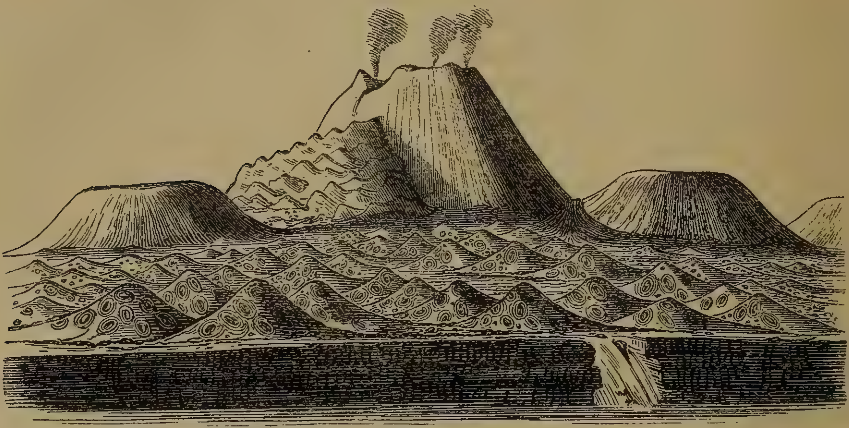


Fig. 2.—*Section of Jorullo.* (After Humboldt.)

Level of original plain.

Fig. 3.—*Plan of Jorullo and the Malpais.* (After Humboldt.)

asperities of this great lava-bed tossed up by jets of escaping steam, and coated over to the depth of a foot or two by a black mud formed from the showers of volcanic ashes mixed with rain-water, which are recorded to have fallen in abundance during and after the eruption; in which superficial mud or clay the influence of the hot vapours escaping through them had produced a concentric concretionary arrangement of particles, such as is often found under similar circumstances in volcanic ash or "wacke." Indeed this crust was so brittle that Humboldt says the feet of the mules broke through it. Consequently, I argued, it was quite unnecessary, for the purpose of explaining the visible results of the eruption of Jorullo in 1759, to imagine a new and unexampled mode of volcanic action, such as the sudden inflation from beneath of a tract of solid horizontal strata into a hollow bladder four square-miles in extent, with other supposed hollow bubbles, large and small, upon its surface.

It was too much, perhaps, to expect that any arguments proceeding from me, an unknown writer at that time (more than thirty years back), should prevail against so great and deservedly esteemed an authority as M. de Humboldt, especially upon a question relating to a volcanic district which he had, as it were, discovered, and which I had not even visited. Neither is it to be wondered at that this notion of the inflation of volcanic hills, like bladders, from beneath, having been thus presented to geologists in the character of an observed fact, should have been applied by other writers as well as by M. de Humboldt himself to many other volcanic formations. In fact, from this supposed example, the theory of upheaval craters (Erhebungskrater), shortly afterwards put forth by Humboldt's compatriot and frequent correspondent, Leopold de Buch, readily and naturally originated. The vaulted crust of the Malpais is, of course, a half-elevated volcanic cone, only needing a little more "pushing up" to become an Etna, a Chimborazo, or an Elburz, in the imagination of the upheavalists. Nevertheless, so thoroughly persuaded am I that M. de Humboldt is completely in error as to this typical example, that I should be quite willing to rest the whole controversy between the rival theories of upheaval and eruption upon this single case*. I stop for a moment to mention, as a parallel example to that of Jorullo, tending to show its very normal and ordinary character, the results of a great eruption of the volcano of Awatscha in Kamschatka in July 1827, visited by Messrs. Portel and Lenz in the subsequent year. They describe a vast stream of trachytic lava as having descended from the rim of the great crater of the mountain, down whose outer flank it now projects in a steep ridge (evidently, therefore, resembling the promontory of lava on the side of Jorullo). At the base of the cone it spread out widely in a high platform,

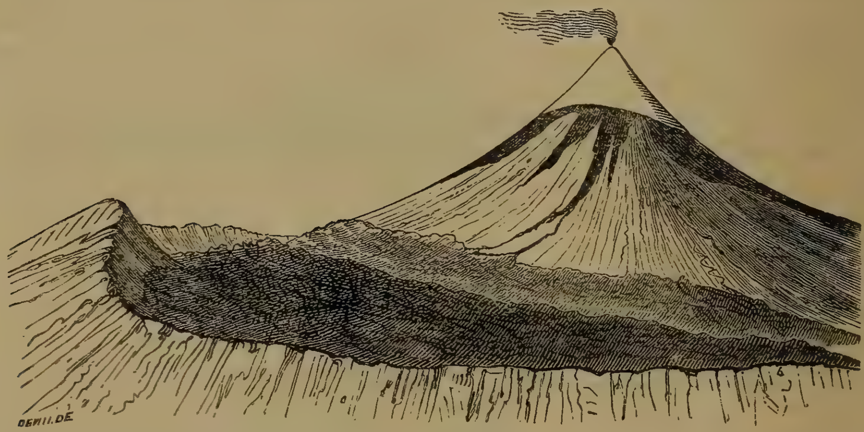
* Jorullo has recently been visited, at the request of M. de Humboldt, by M. de Saussure; and I understand from Sir Charles Lyell that the latter geologist has communicated to him his conviction that upheaval played no part in its production, and that an abundant stream of lava had flowed from its crater and deluged the plain at its foot. M. de Saussure will, no doubt, before long publish his observations in detail.

called by the natives "the burnt field." Its surface is covered, like the "Malpais" of Mexico, with a thick bed of ashes, and from this rise numerous small knolls or hillocks some 10 or 12 feet high, and about the same in diameter at the base, from each of which issued, at the time of their visit, "fumaroles," or streams of hot vapour having an odour of sulphuretted hydrogen. Here, as at Jorullo, it is evident that abundant showers of ashes gave to the superficial asperities of the great lava-bed (which discharged vapours as usual, so long as the interior retained its heat) the same conical or dome-shaped figures that we see given by a deep fall of snow to accidental protuberances on the surface of any rough field. Indeed, I observed a precisely similar phenomenon produced by the eruption of Vesuvius of 1822, as I remarked in a paper read before this Society in 1827.

The upheaval or "blister" theory having been, however, thus originated by M. de Humboldt, was adopted, and further developed by M. de Buch in his work on the Canary Isles.

This author says, of the Peak of Teneriffe itself (fig. 4), notwithstanding that he describes its only visible part (the surface) to be composed of ejected pumice and streams of glassy lava, which are admitted to have repeatedly flowed down the steep sides of the cone

Fig. 4.—*Peak of Teneriffe, as seen from the margin of the Cirque.*



from its summit *—thereby showing the cone to be of a purely *eruptive* origin, so far as it can be observed:—

"It (*i. e.* the entire cone of the Pic de Teyde) has been produced by the '*upheaval*' of a mass urged upwards by the force beneath, which struggled for a vent, and which while forcing a passage in the middle of the crater of elevation (the surrounding cirque) *lifted up the mass above it* in the form of a dome †."

This assertion, be it remarked, is made dogmatically, without any attempt to support by argument so strange a proposition, and one so contrary to received notions—nay, even to the facts he himself relates as to the cone being visibly composed of loose pumice and lava-streams.

In the same manner, in speaking of Vesuvius, in the latter part

* Canaries, p. 196. † Ibid. p. 202.

of the same volume, M. de Buch asserts that "It sprung up at its origin, in the time of Pliny, ready-formed, as we see it" (*Le volcan, tel que nous le voyons encore, est sorti, à cet époque, tout formé, du sein de la terre*). "It was *not* formed," he goes on to say, "by successive out-flowings of currents of lava; on the contrary, its height has, since that epoch, A.D. 79, been constantly diminishing*." Again, of Etna, M. de Buch says, "We cannot refuse to see in it an individual, so to speak, arrived at perfection at the moment of its birth. . . . . It could not have been the result of slow and irregular growth, by successive eruptions. *Its form is too regular and symmetrical for such an origin* †."

M. Elie de Beaumont, who, with M. Dufrénoy, subsequently to M. de Buch, took up and maintained the upheaval-theory, similarly says of the same mountain, Etna: "*One day* the internal agency which had so frequently disturbed the 'terrain' (which he had described as, up to that time, a nearly horizontal plain, composed of volcanic strata), having exerted an extraordinary degree of energy, broke through and upheaved it. *From that moment Etna became a mountain.*" He goes on to reject the idea of its upheaval having been gradual, and says, "It was effected *suddenly and at one stroke*‡."

So, again, M. Dufrénoy says of Somma, "The lavas of which it is composed were formed in horizontal sheets, under the sea"—"*se sont épanchées en nappes horizontales*;" and "it was after this that Somma was *upheaved at once* §."

I quote these passages from the works of the chief advocates of the upheaval-theory in order that there may be no misunderstanding as to what it really is, and lest it should again be said (as I have heard it said in this room) that it is only a question of degree,—that both parties to the controversy may be right to some extent,—that truth may lie between them, and so forth. These convenient modes of compromising unpleasant differences of opinion will not apply here. *It is a question that admits of no compromise.* It is not as to whether some small proportion of the salient relief of a volcanic cone or mountain, or of the angle of elevation of its outer slopes, or the partial disturbance of some of its component beds, may be due to occasional earthquake-shocks or other subterranean elevatory impulses, accompanied by the injection of lava into the internal fissures thus formed (afterwards hardened into solid dykes), *during the successive eruptions of the volcano*. That much will be disputed by no one of the Eruptionists (as I may call them), certainly not by myself, who have always described this inward distension of a volcanic mountain in habitual or occasional eruption as part of the gradual process by which it was formed ||. But such slow accretions to its solid internal bulk are the very reverse of the process imagined by the Upheavalists.

* Canaries, p. 342. † Ibid. p. 326.
‡ Recherches sur le mont Etna, pp. 188–193.
§ Terrains de Naples, p. 360.
|| See 'Considerations on Volcanos,' 1825, p. 156, and Trans. Geol. Soc. Lond. 2 ser. vol. ii. p. 341, 1827.

They, as I have just shown, insist upon the entire volcanic mountain, just as we now see it, having sprung out of the ground at one jump—blown up suddenly, like a bladder, by a single effort,—the whole amount of inclination exhibited by its outer slopes, or by its component beds, being the result exclusively of the sudden and simultaneous "swelling up" of its entire mass of beds from a previously horizontal, or nearly horizontal, position.

The extracts I have given from their works place this beyond dispute.

But, indeed, this doctrine, in its extremest sense, is a necessary consequence of the argument on which it is based by the Upheavalists, namely, the asserted impossibility (said to have been demonstrated by the observations of M. Elie de Beaumont on Etna) that any bed of lava, other than a mere scoriform strip, or string, or thin crust, has or could have consolidated at an angle of slope exceeding 2° or 3°, or at the very outside 5°. This is an argument which, as has been justly observed by Sir Charles Lyell (in the last edition of his 'Manual', p. 507), applies, of course, to the very uppermost bed of lava to be found upon the slope or in the framework of a volcanic cone, quite as much as to any of those beneath it. If, then, the law laid down by M. de Beaumont is a true one, every cone or volcanic mountain upon or near whose external surface any solid bed of lava occurs having a greater inclination than 3° or 5° (a description which includes probably all the known volcanic mountains in the world) must have been upheaved entirely, as we now see it, from a nearly horizontal position *since the deposition of that upper or most recent lava-stream.*

I shall presently advert to the baseless character of the assumed law as to the non-consolidation of lava upon steeper slopes than 3° or 5°, laid down by M. de Beaumont.

Meantime, the question being thus cleared from all ambiguity, the first remark that suggests itself is, that the upheaval-theory absolutely ignores all volcanic eruptions whatever from the central vent of a volcanic mountain subsequent to its original creation (or rather, according to their notion, of its *inflation*)—at least as having erupted anything beyond gases and a sprinkling, perhaps, of ashes. In fact, in this view, volcanic mountains exist independently altogether of volcanic eruptions, and might, nay, would, be just what they are, even though they had never been in eruption at all*. Of course, the fact of eruptive phenomena having repeatedly taken place from such mountains, even within historic and recent times—eruptions of intense violence, and which threw up, often through long periods, prodigious quantities of fragmentary materials, and poured forth from the central vents or their immediate vicinity abundant streams of lava,—could not be altogether denied. M. de Humboldt, indeed, in some passages would appear by no means to

* Indeed, de Buch expressly says of the basaltic (doleritic) beds that compose the bulk of Etna, referring to those seen in the escarpments of the Val del Bove, "These beds derive their origin from phenomena anterior to the action of the volcano itself."—*Canaries* (Paris edit.), p. 328.

undervalue the accumulative powers of the eruptions of such mountains. He speaks, for example, of "the mighty devastating lava-pouring volcanos of Etna and the Peak of Teneriffe, and the abundant scoriæ-ejecting volcanos of Cotopaxi and Tunguragua *." But the theory of upheaval certainly fails to answer the plain question, What becomes of all these abundantly erupted matters, if, in the course of ages, they do *not* accumulate into mountains? That theory unquestionably requires that the lavas and scoriæ thrown up from the central and higher vents of any volcanic mountain since its original elevation should have left no traces (or next to none) on its summit or slopes—should scarcely in any perceptible degree have increased its height or bulk. It is not for me to reconcile this strange inconsistency. It is admitted, no doubt, that some parasitic cones of scoriæ and beds of lava due to eruption are to be found about the *base* of a volcano, where the inclination of the slopes is less than 3° or 4°. But even on this, as on other points, the upheavalists are by no means consistent with one another, or with themselves. For example, M. Dufrénoy, in his description of Vesuvius, asserts that not only that mountain, but also the four small parasitic cones formed on its lower slope, immediately above Torre del Greco, by the eruption of 1760, were "caused by an upheaval of pre-existing beds of scoriæ and lava, and *not* by the accumulation of ejected fragments †;" and he even attributes to the same origin (in his own words, "upheaval, not accumulation") the formation of the small cones formed in June 1834, upon the outer flank of the principal cone, and in the interior of its crater.

On the other hand, M. de Beaumont considers Vesuvius itself, as well as its parasitic cones, to be of eruptive origin, and in his 'Memoir on Etna' admits all of the three or four hundred parasitic cones which stud the flanks of that mountain—many of them, such as the Monte Rossi, exceeding in bulk ten times those of Torre del Greco—to be true "cones of eruption, the product of the accumulation of ejected matters." Nay, he allows the same eruptive origin to the whole terminal and central cone of Etna, containing the existing crater, and which rises more than a thousand feet above the 'Piano del Lago,' a sort of platform at its base ‡; and it is only to the *intermediate cone* terminating upwards in this platform, and downwards in the lower slopes studded with cones of eruption and coated with their lava-streams (which he calls "*la gibbosité centrale*"), that he applies his theory of sudden upheaval. Moreover, M. de

* Kosmos, iv. p. 164.

† Mémoires sur le Vésuve, pp. 331 & 318.

‡ I may say here that the platform of Etna, the Piano del Lago, presents no difficulty requiring so extraordinary a solution. It is without doubt merely a truncation of the ancient cone of Etna at the period of some early paroxysmal eruption,—the crater then formed having been subsequently filled up by eruptions, and the upper cone raised within a still later period upon the flattened summit so produced. It is, in fact, a parallel case to the platform which, for some years before 1822, formed the summit of Vesuvius, and upon which several minor cones with craters were at intervals thrown up, and to the precisely similar state of things which, after the filling up of the crater formed in 1822, existed on the same summit from 1834 to 1850. (See fig. 5, p. 517, and fig. 17, p. 532.)

Beaumont likewise admits the Peak of Teneriffe, as well as Vesuvius, into his category of cones of eruption and accumulation; nay, he even instances their "regular and straight slope from top to bottom" as the distinguishing and characteristic feature of eruptive cones *.

So, too, MM. de Buch and Humboldt both recognize as "cones of eruption and accumulation," not only the lateral or parasitic cones of Etna, but the thirty or more cones of Lanzarote in the Azores, and all the puys or scorial cones of Central France, about a hundred in number, and many of them of great size.

It would appear from these admissions as if it were only to the very largest volcanic mountains composed of repeated beds of lava and conglomerate, which are generally supposed to be the product of numerous successive eruptions from the same central vents, that the majority of the upheavalists—MM. de Humboldt, de Buch, and de Beaumont—apply their theory. This, however, is not the fact, because these same geologists, one and all, join with M. Dufrénoy in asserting all the small tuff-cones and craters of the Phlegræan Fields near Naples to be the result of upheaval alone, including even the Monte Nuovo itself, which was thrown up in the year 1538 by an eruption that lasted three days and nights, according to the testimony of numerous observers, several of whom have left us a clear account of the phenomena!

Thus, to recapitulate a few of the inconsistencies and discrepancies of the upheavalists, de Buch and Humboldt assert both Somma and Vesuvius, the Peak of Teneriffe and all Etna, "as we now see them," to be due to sudden upheaval, although, at the same time, they admit them to have been in active eruption for multiplied ages. M. de Beaumont declares Somma, and the nucleus or central portion alone of Etna, to be upheaved, but Vesuvius, the Peak of Teneriffe, and the upper cone of Etna to be eruptive, as well as all the parasitic cones of the latter mountain. M. Dufrénoy attributes Somma, Vesuvius, *and its parasitic cones* to upheaval alone. And while all admit the minor cones and craters of Auvergne, the Velay, and Lanzarote to be eruptive, all declare those of the Phlegræan Fields to be solely due to upheaval!

These inconsistencies of the advocates of the upheaval-theory render it difficult to suppose that they understand it themselves. It is, indeed, a hopeless task to endeavour to discover in their works any clear notion of what they consider to be the distinctive character of "upheaved" as contrasted with "erupted" volcanic cones.

One of them, however, M. de Beaumont, seems to recognize the necessity of some guide of the kind, and undertakes the task. He declares the distinction to consist in "the continuous rectilinear slopes" of erupted cones; while those of upheaved cones are "more irregular, and graduate insensibly towards horizontality as they approach the base †." And it is on this ground expressly, of regularity of form and slope, that he asserts Vesuvius, the Peak of Teneriffe,

* Mémoires, vol. iv. p. 157. † Ibid. p. 96.

and the terminal cone of Etna to be eruptive cones *. But, on the other hand, M. de Buch, in the passage I have already referred to, affirms the extreme regularity of the entire figure of Etna to be a proof that it *could not* be the product of eruptions, but must have been upheaved at a single stroke, "*à l'instant même de sa naissance* †." In fact, M. de Buch's test is the precise reverse of M. de Beaumont's.

Suppose, however, we take M. de Beaumont's as that of the latest authority on the point. Surely it is trifling with the subject to rest so important a distinction as to origin upon a difference in outline so slight, so disputable, nay, so necessarily variable under varying circumstances of composition, dilapidation, &c., independently of all question of origin. In the first place too, it is undeniable that many, perhaps the majority of the acknowledged cones of *eruption* about Etna, and in Central France, show a sloping outline by no means "rectilinear," but sweeping downwards in a gradual curve that lessens in steepness till it meets the base, which is M. de Beaumont's characteristic of an "*upheaved* cone." In the second place, the slightest consideration makes it obvious that great differences in this respect *must* be occasioned by casual differences in the size, shape, or mineral character of the ejected fragments, by their more or less heated state and consequent coherence or non-coherence at the time of their fall and accumulation, by their greater or less degradation by storms of rain accompanying the eruption, or by a longer or shorter subsequent exposure to atmospheric influences. In the case of the larger volcanic mountains, if we suppose them the product of repeated eruptions, a graduated slope towards the base must necessarily have been occasioned, not only by longer exposure to the agents of degradation, but still more by the accumulation of the lavas and scoriæ emitted from lateral vents on the lower flanks of the mountain. Indeed, M. de Beaumont, by admitting the many

Fig. 5.—*Outline of Etna, as seen from near Catania.* (From Mém. Soc. Géol. de France, vol. iv. pl. 2.)

hundred parasitic cones of Etna and their lava-streams to be eruptive, himself accounts, on the theory of accumulation, not of upheaval, for the graduated slope of the mountain as a whole into the plain around. And, in truth, the visible portion of his "central up-

* Mémoires, iv. p. 157. † Canaries, p. 326–7.

heaval cone," intermediate between the terminal cone and the lower region of parasitic eruptions, has that very "continuous rectilinear slope" which he announces to be the special characteristic of an "eruptive cone" (as may be seen in fig. 5, from M. de Beaumont's own view). So that his test, if it were worth anything, would reverse his own conclusion.

The outer slopes of a volcanic cone, almost without exception, correspond to the internal arrangement of its component beds or strata, which have consequently what is called a *quaquaversal* dip from the central axis. This general rule is not disputed, but rather insisted on by the upheavalists. Yet this particular and very remarkable arrangement is exactly what would be necessarily occasioned by the falling of successive layers of ejected fragmentary matters, and the flowing of successive streams of lava from a central vent, round which they must accumulate in what may be called an "annular talus;" while, on the other hand, the upheavalists have failed to show how such an arrangement is likely to be, or indeed could be, *so uniformly* produced by upheaval. There are said to be, and possibly there may be found, two or three instances of a nearly similar quaquaversal stratification in non-volcanic rocks. Among the infinite diversity of foldings and squeezings which such stratified rocks have undergone by repeated elevations and subsidences, it would be indeed extraordinary if here and there something of the kind should not have occurred. But what the upheavalists have not attempted to account for is, that whilst in non-volcanic strata such instances, if to be met with at all, are the rarest possible exceptions, *in the strata composing volcanic hills they are the universal rule.* If the same process of upheaval has occasioned the elevation of both classes of rocks, how is it that the character and amount of elevation observable in the two are not the same, but on a general view so completely different? How do the upheavalists account under their theory for the broad fact, that in all volcanic cones, however large, the inclination of the component beds is so similar, and uniformly limited to a maximum of 30° or 40°—in short, precisely that of a talus? How has it happened that so tremendously violent a process as the (supposed) sudden upheaval of a mass of horizontal strata some thousands of feet in thickness and hundreds of square-miles in area, into a mountain like Etna, and numerous others, has in every case tilted these strata with such extreme regularity in a circular quaquaversal arrangement, dipping almost symmetrically at about the same moderate angles? Why are the strata, if upheaved by violence, not found in long linear anticlinal ranges, and occasionally dipping at angles of 60°, 80°, and 90°, or completely vertical, like the stratified rocks, which no one doubts to have suffered violent elevation?

Again, M. Elie de Beaumont illustrates the kind of elevatory shock by which he supposes a volcanic cone to have been upheaved and its crater formed, by that of a sudden blow given from beneath to a horizontal surface of glass or ice, producing what he calls an *étoilement*, or *star*-fracture. No illustration could be more fatal to his own theory; for (as Sir Charles Lyell and M. Prévost have both remarked) the peculiar characteristic of a starred opening is the formation of fissures radiating from the centre of impulsion, but all *widening inwardly towards it*, which is precisely the reverse of the universal character of the fissures, ravines, or "barancos," radiating from the centre of volcanic mountains, all of which, without exception, I believe, *widen outwardly* towards the base of the mountain, according to the usual habit of waterworn ravines, which they no doubt are for the most part, though some may have had their origin in earthquake-cracks. Indeed these radiating clefts or ravines, which are very characteristic of volcanic mountains (being the natural result of their regularly conical or pyramidal form, and the rapid degradation from rain-fall to which their fragmentary materials are generally liable), rarely penetrate the rim or border of the central crater at all. And how a cone possessing an unbroken annular central crater can be supposed to represent an *étoilement* or starred fracture, or to have been raised by a sudden and violent impulse from beneath, acting upon solid horizontal superficial strata, passes comprehension.

It seems indeed strange that the upheavalist should fail to perceive that his own arguments and illustrations tell strongly against his own theory—that the generally unbroken and regularly circular lip of a volcanic crater, as well as the extremely regular and uniform inclination of the outer slopes and parallel component beds of a volcanic cone (which is so remarkable that observers can almost always recognize a volcanic mountain at any distance by its peculiar talus-like outline), so far from serving as arguments in his favour, and distinctive characteristics of upheaval, are, to ordinary minds, the very reverse.

But there is more yet to be said on this part of the subject. In many volcanic districts, for example near Naples, in the Galapagos Isles, and several other localities, cones and craters occur composed of beds of tuff or pumice-ash and scoriæ, through which the abrasion of torrents or of the sea-waves has exposed favourable cliff-sections, exhibiting, besides the usual outward concentric anticlinal dip, an inward synclinal one, equally concentric, *towards* the interior of the crater. The Capo di Miseno, and the isles of Nisida and Procida, and the Monte Barbaro near Pozzuoli, are examples of this remarkable arrangement, which, on a little consideration, will appear to be the natural result of the process of eruptive accumulation,—the fragments that fall upon or roll down the outer slopes of the cone from the beginning forming beds with an outward quaquaversal dip,—those that fall in the interior of the crater, especially as the eructations diminish in violence towards the close of the eruption (and consequently become unequal to the clearance of the whole area of the channel of discharge), accumulating in an inner talus having a concentric dip towards the centre. (See fig. 6.)

In my volume on Volcanos, published in 1825, I gave both an ideal section of a cone so formed (of course, by a single eruption) (fig. 6), and a sketch of the natural sections of some actually exhibited, for ex-

Fig. 6.—*Ideal section of a simple Volcanic Cone, formed by the accumulation of erupted fragmentary matters from a single vent.*

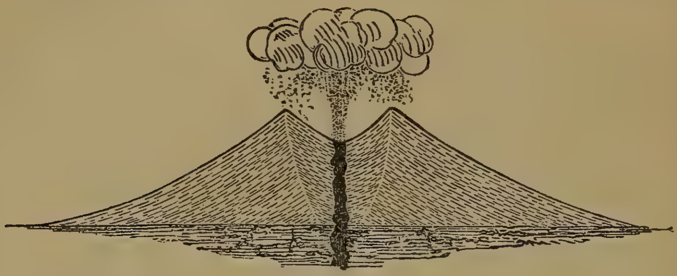


Fig. 7.—*Natural Cliff-section of a simple Cone of Eruption: the Capo di Miseno, near Naples.*

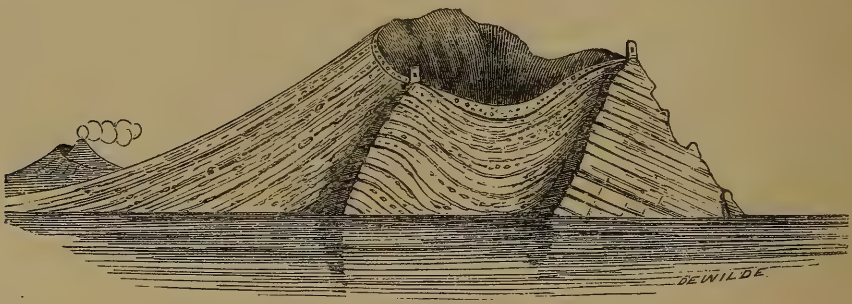
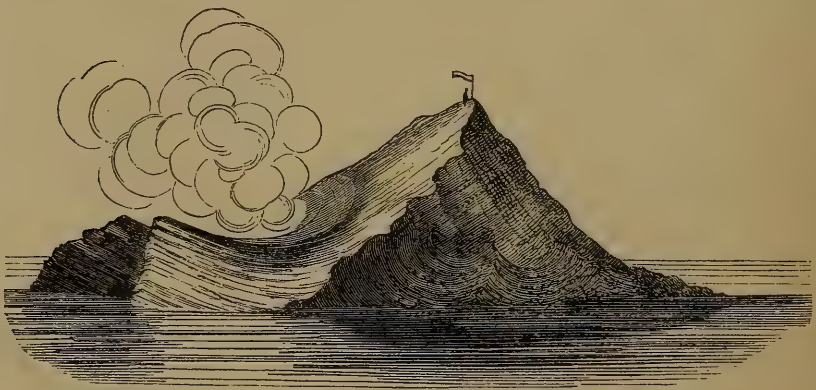



Fig. 8.—*Graham Island, as it appeared in September* 1831.



ample, in the Island of Nisida and the Capo di Miseno. The latter is here reproduced (fig. 7), as also a view of Graham Island (fig. 8) taken, just before its final disappearance, by M. Joinville in September 1831, in which may be seen the same internal dip of the beds that composed the nucleus of the cone, which, from their proximity to the vent, were no doubt more firmly compacted by heat than the outer strata, and from this cause no less than from their central position were likely to resist longest the destructive action of the waves. Such, too, is exactly the structure of the small crateriform island on the coast of St. Michael in the Azores, near Villafranca, described by Mr. Darwin ('Volcanic Islands,' p. 108); and other instances will, no doubt, occur to every one who is conversant with volcanic districts.

Now it seems quite impossible to reconcile this circular *anticlinal* dip with the theory of upheaval; for, even if it were conceivable that horizontal beds may be tilted uniformly round a central opening (although I cannot admit even this where the ring is entire and no fractures appear through its ridge), it is wholly inconceivable that such a process *could* generate a solid annular bank with a regular double or anticlinal dip all round. This insuperable difficulty is, however, quietly passed over by the upheavalists by the employment of the convenient phrase, "local convolutions of the elevated strata."

With similar facility—not to use any stronger phrase—M. Dufrénoy meets the obvious objection made to his theory of the sudden upheaval of the Monte Nuovo, that the Roman buildings standing close to its base have remained perfectly vertical and their cornices perfectly horizontal, by the bold supposition that, after all, the Monte Nuovo perhaps existed long before the Roman era, and was only sprinkled over with a light coat of ashes by the eruption of 1538*; although, according to the unanimous testimony of all contemporary observers, it was then first seen to be formed, upon the previously flat shore, by eruptions of large stones, scoriæ, mud, and ashes from the spot—eruptions which were so abundant during two consecutive days and nights, that the finer particles actually covered the ground to a distance of seventy miles†,—a phenomenon therefore that could

* Mémoires, &c. p. 278. So also Von Buch's 'Iles Canaries,' p. 347.

† Letter of Francesco del Nero.—See Lyell, 'Principles,' p. 369. In the volume (now in the British Museum, the gift of Sir W. Hamilton,) printed at Naples in the very year of the eruption, Signor Marco Antonio Falconi, an eye-witness of it, thus writes:—"Stones and ashes were thrown up, with a noise like the discharge of great artillery, in quantities which seemed as if they would cover the whole earth; and in four days their fall had formed a mountain *in the valley between Monte Barbaro and the Lake Averno*, of not less than three miles in circumference, and almost as high as Monte Barbaro itself,—a thing incredible to those who have not seen it, that in so short a time so considerable a mountain should have been formed." Another account in the same volume, by Pietro Jacobeo di Toledo, describing the same fact, adds, "Some of the stones were larger than an ox. They were thrown up, the larger ones, about a cross-bow's shot in height from the opening, and then fell down, some on the edge of the mouth, some back into it. The mud ejected [ashes mixed with water] *was at first very liquid, then less so*, and in such quantities that, with the help of the afore-mentioned stones, a mountain was raised a thousand paces in height, on the third day. I went to the top of it and looked down into its mouth, in the

scarcely fail to create such a cone as we now see around the orifice of projection—which is not nearly so big as the Monte Rosso and many other acknowledged cones of eruption.

The unwillingness of M. Dufrénoy to admit that Monte Nuovo was the product of eruptions is by himself grounded on the perfect similarity of the tuff-beds of which it is composed to those which are so generally spread over the Phlegræan fields, and compose the older cones and craters around. It was clearly seen by him, as well as by all the other upheavalists (who are for once agreed on this point), that, if the upheaval-theory is renounced in regard to the former (the Monte Nuovo), it must be equally given up as respects the other hills, including even Somma itself, round which these tuffs mantle conformably. In fact Monte Nuovo is evidently the key to the origin and mode of formation of the neighbouring cones and craters; and it was therefore necessary at all risks to make it out an upheaval cone. Consequently the bold assertion is advanced by all of them, that Monte Nuovo was not a new hill in 1538—that it was *not* formed at that time, nor by the eruption to which all contemporary observers attribute its production!

I may stop a moment here to say that the similarity of the tuff-beds of which Monte Nuovo is composed to those of the surrounding more ancient crater-hills, is, of course, owing to the eruption that formed it having been, as in their case likewise, subaqueous, or on the shallow margin of the sea, and the matter thrown up chiefly pumice or felspathic scoriæ, which, triturated into ashes by repeated ejection and mixed by agitation with the sea-water into a kind of mud or mortar, hardens into a tough tufa*. The later explosions of the eruption being probably subaërial, or not so much mixed up with water, the superficial beds are found to consist of incoherent tuff, lapilli, &c., remaining just as they fell from the air. And this is the general composition and arrangement of all the tuff-hills of the district of the Phlegræan fields†. An exact parallel in every particular to these tuff-craters seems, from the statement of Mr. Darwin, to occur in the Galapagos Isles near Banks's Cove. He describes one 500 feet in depth and $\frac{3}{4}$ of a mile in diameter,—the lower beds being

middle of the bottom of which the stones that had fallen there were boiling up just as in a great caldron of water that boils on the fire."

* In the latter days of the Vesuvian eruption of 1822, the fine ashes thrown out by the volcano, and which, mixed with rain-water into mud, were washed down the slopes of the mountain, formed a crust of indurated tuff so compact and hard that it required a pickaxe to break it. Some of its beds were pisolitic, the drops of rain having aggregated the fine ashes into globular concretions. It was an alluvium of this character (mud-lava, *lava di fango*) which overwhelmed Herculaneum, while Pompeii, lying beyond the base of the mountain, was buried under the loose ejecta of the same eruption, falling upon it from the air. The trass of the Rhine volcanos, and the Moya of the Peruvian volcanos are the result of a similar admixture of water and felspathic ash. In these latter cases, however, the contained infusoria or fish proved the mud-flood to have been produced by the debacle of crater-lakes. The mud-eruption which in great part formed Monte Nuovo is well described by one of the eye-witnesses of the phenomenon in Sir W. Hamilton's book already quoted.

† This superficial bed of incoherent tuff may be seen on the cone of Miseno. See fig. 7 above.

formed of compact tuff, appearing like a subaqueous deposit; the upper of a harsh, friable, light, and occasionally pisolitic tuff; the beds of each dipping regularly away on all sides from the crater, at an angle of from 25° to 30°. But within the crater are other strata of tuff dipping at a still higher angle inwardly. Mr. Darwin says truly of them, that the appearances could not possibly have resulted from upheaval. Professor Dana describes other tufa isles of the Pacific in similar terms*.

The tuff-cones and craters of the Phlegræan fields, indeed, only differ from the cones and craters of Lanzarote, Etna, or Central France in being composed of pumiceous (*i. e.* felspathic) scoriæ and ash instead of basaltic scoriæ and ash, and in being of subaqueous instead of subaërial origin, in consequence of which their materials are more consolidated and stratified, and their form wider, broader, and more openly spread out than the latter subaërial cones. In other respects, of structure, dip, and direction of the component beds, both classes are so exactly alike, as to make it a matter of astonishment that an entirely different and opposite mode of production should be attributed to them by the upheavalists†; more especially since, in the case of the Monte Nuovo at least, there is ample contemporary authority from bystanders for the occurrence of those very copious eruptive ejections which these geologists admit to have given birth to the cones of Etna and France.

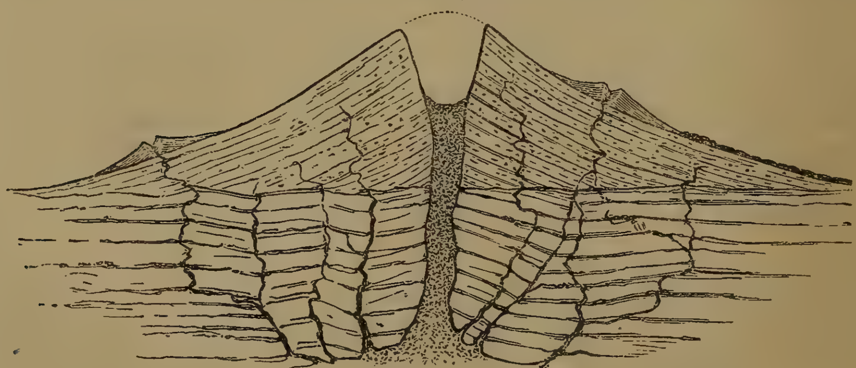
It is a similar dilemma which has driven the upheavalists into the inconsistencies already referred to respecting the mode of formation of Vesuvius. The perfect analogy of its chief cone, in form, structure, and composition, to the half-encircling cone of Somma, from the centre of whose crater it rises, makes it all but impossible to attribute a totally distinct origin to the two. When, immediately after the great eruption of 1822, I stood on the acute ridge of the prodigious crater that had been drilled through the solid heart of the cone by the gaseous explosions of the previous twenty days, and marked the exact resemblance of its internal cliff-sections to those of the half-encircling crater of Somma, which were within my view at the same moment, I could not doubt that both the inner and outer concentric cones and craters owed their origin to similar developments of eruptive violence. I could as soon hesitate to believe that the separate pieces of a turner's nest of boxes, or the flower-pots that we buy, fitting one into the other, were respectively fashioned by the same process. The irregular beds of lava and conglomerate traversed by dykes, which visibly composed the cliffs of either crater, dipped on all sides away from the same centre, at the same angle, parallel in either case to the outer slopes of each cone.

* U.S. Expl. Exp. vol. i. p. 328.

† M. Rozet, one of the disciples of this school, thus describes all the craters of the Phlegræan fields: "They are *not eruptive craters*, but simply 'cirques,' opened in the pre-existing horizontal tuff-beds." They are "dislocations en forme de cirque." "C'est une grosse bulle de gaz, qui, après avoir formé une ampoule dans les tuffes horizontaux, a fini par les crever." (Rozet, Mém. Soc. Géol. de France, 2 sér. part 1, p. 140.)

The broken edge of the new crater's rim showed, still smoking, sections of the lava-currents which, for some years, I myself had watched successively flowing down the sides of the cone from minor eruptions at its summit, and leaving solid ribs of lava-rock upon its surface-slopes, up which ribs I often climbed the cone. I had, through the same period, seen an abundance of fragmentary lava and scoriæ discharged from various upper mouths, forming hillocks and protuberances upon the rude platform which then surmounted the cone; one of which minor cones, measuring no less than 450 ft. in height, was thrown up within three months in the early part of that year (1822), a fact confirmed by the testimony of MM. Monticelli and Covelli. And with this positive experience of the rapid growth under my own eyes of the cone of Vesuvius within two or three years only of comparatively moderate activity, and with the knowledge derived from authentic records of some fifty or more paroxysmal eruptions, many of them of greater violence, having occurred from this same volcanic vent during the last eighteen centuries, can I entertain any respect for a theory which tells me that the entire mountain was formed, just as we now see it, in the year 79, by some unintelligible, or at least unexampled, process—that it has not since that epoch grown at all by the accumulation of the erupted matters, whether lavas or scoriæ—nay, that it has rather diminished than increased in bulk and height from the time of its original inflation? For that is the assertion put forth by de Buch, and endorsed by M. de Humboldt! Have we not also a right to ask those who refuse to believe the still *larger* volcanic mountains of either hemisphere to be built up from the accumulated lavas and fragmentary ejections of *their* repeated eruptions, what else can have become of all these erupted matters? Many such volcanos are known to have been in frequent or habitual eruption during even recent historical times, ejecting vast quantities of scoriæ, pumice, and ashes, and enormous streams of lava from their central crater or its immediate vicinity. It is fairly presumable that for long previous ages similar eruptions had been taking

Fig. 9.—*Ideal section of a Volcanic Cone, formed of the products of repeated Eruptions.*



place from the same vents. The eruptionists admit that *a single* eruption will give birth (*by accumulation, not upheaval*) to a hill of the size of the Monte Rosso, the Puy de Come, or the great cones of Lanzarote—hills 600 or 700 feet in height, and of proportionate bulk. What else, then, may we not ask them, *can* have resulted from the accumulated products of innumerable eruptions repeated for ages from the same vent or its immediate neighbourhood, but just such mountainous excrescences as we see in the larger volcanic cones? And when we find them, on examination, to be composed of beds of lava and scoriæ or pumice-conglomerate, rudely alternating, and dipping outwardly on all sides away from the central vent, at the same talus-like angle of inclination as the most recent beds that have been seen to flow down or fall upon the outer slopes, can we entertain any doubts as to the mode of production of the entire mountains? (See fig. 9.) Or is it consistent with sound philosophy to hunt about for some other and extraordinary hypothesis to account for it?

*Consolidation of Lava on Steep Slopes.*—The only argument of any seeming weight that has been adduced by the upheavalists in support of their original views, is based on the assertion of M. Elie de Beaumont, as the result of his observations on Etna and elsewhere, that no lava-current can, or has been ever seen to, consolidate upon a slope having an inclination of more than 3° or at most 5°, and that all lavas which have flowed down declivities exceeding this angle have left no other traces than mere narrow and thin strips or a few loose scoriform cakes upon such slopes. It is, in fact, upon this assertion of M. de Beaumont that de Buch, Humboldt, and Dufrénoy professed to rest their opinion that all volcanic cones containing beds of solid lava dipping at angles of from 5° to 35° *must* have been *upheaved* since the flowing of such lavas.

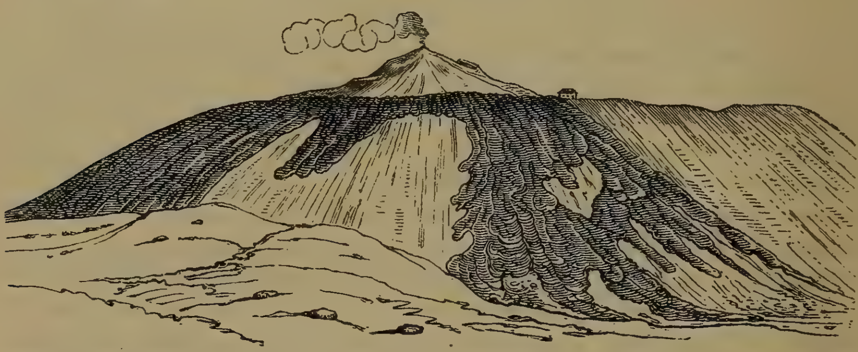
So far as Etna is concerned, I leave this misrepresentation of the fact to be dealt with by Sir Charles Lyell, who, in the elaborate paper lately read by him before the Royal Society, and which will shortly appear in the 'Philosophical Transactions,' has amply refuted it from his own recent observations. But I may assert with confidence that this pretended law as to the consolidation of lavas is directly at variance with the commonest facts observable in perhaps all volcanic districts. I have already alluded to the lava-streams which I myself saw harden (and over which I frequently walked), on the slopes of Vesuvius, at an angle of 33°, in the years 1819–22*. Among the Puys of Central France many of the most recent lava-streams, such as those of Nugère, Graveneire, and Pariou in Auvergne, that of the Mont Denise and others near Le Puy, several also in the Vivarais, have congealed in bulky masses at angles of from 10° to 30°, both upon the outer slopes of the contemporaneous eruption-cones, and in portions of their headlong course down some of the steep river-channels which they have occupied—places in which any notion of upheaval is out of the question. A recent visit in the past summer to these localities enables me to make this assertion with

* And many similar examples are at this moment to be observed in the streams produced from the same volcano by the eruptions of the last five or six years. (See Roth, Vesuv. 1858.)

confidence. M. de Buch himself describes the steep slopes of the Peak of Teneriffe as encrusted with numerous currents of glassy lava (obsidian)*, which he admits to have been erupted near the summit and to have flowed down the sides of the cone, an observation which alone should have led him to discredit De Beaumont's theory of consolidation.

Again, he speaks of some of the cones of Lanzarote, which he admits to have been formed by eruption, as having vast massive basaltic currents of lava "like black glaciers precipitating themselves from the summit to the base of each cone." He represents himself as painfully climbing for an hour and a half up the steep and rugged surface of one of these "cheires," to reach the high margin of the crater. Humboldt describes himself as doing the same thing in his attempt to reach the source of the great lava-stream of Jorullo on the summit of the cone from whose crater it issued; and in the drawing he gives of it, the bulky promontory of basaltic lava-rock is represented as leaning against the cone at an angle of more than 35°. (See fig. 1, p. 510.) Even M. de Beaumont is forced to recognize the lava-streams that have hardened on the steep slope of the cone of Etna as eruptive. He says, "La croûte de l'Etna est évidemment une croûte d'éruption†"—which indeed it is, as may be seen in fig. 10.

Fig. 10.—*View of the Summit of Etna, and the Lavas that encrust its slopes towards the Val del Bove.* (After W. Sartorius de Waltershausen.)



M. de Beaumont admits the same of Teneriffe (the Peak), which he actually classes as a cone of eruption, thereby differing from de Buch, and, in my view, giving up his whole theory, since the slopes of the Peak have a higher angle of elevation than those of the outer "cirque," or of the mass of Etna. (See fig. 4, p. 512.)

Mr. Darwin gives a description, among the numerous unquestionable craters of eruption in the Galapagos Islands, of five in Albemarle Isle, from 4700 to 3720 feet in height, with craters three miles and upwards in diameter, "over the lips of which great caldrons, or from orifices on their summits, deluges of black lava have flowed down their steep and naked sides." In all these cases the lavas clearly consolidated in sheets, beds, or bulky masses, at very high angles of incli-

* Canaries, p. 186. † Mémoires, vol. iii. p. 207.

Fig. 11.—*Volcano of Bourbon.* (After Bory de St. Vincent.)

Fig. 12.—*Pillar of Lava in Tahiti.* (From Dana's 'Geology of the U. S. Exped.')

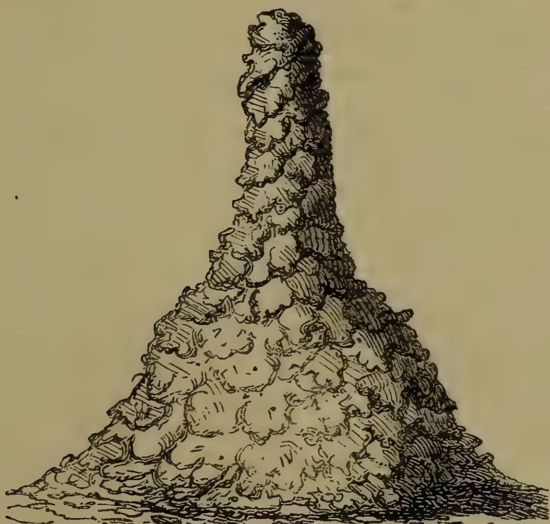
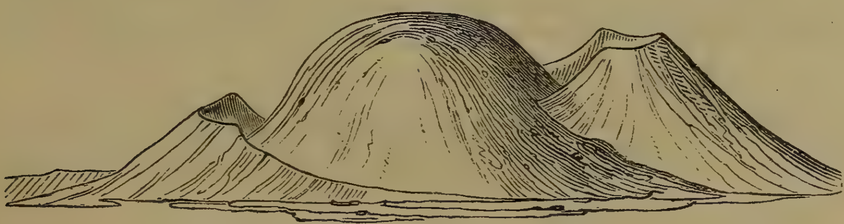


Fig. 13.—*Profile of the Puy de Grand Sarcouy (trachyte), between the Puys de Goule and Petit Sarcouy (Cones of Scoriæ), Monts de Dôme, Central France.*



nation. So, again, Dr. Junghuhn describes in Java numerous volcanic mountains from 4000 to 12,000 feet high, from the highest summits of which streams have flowed of trachytic or basaltic lava, and hardened on their slopes. The volcano of the Isle of Bourbon has emitted many very copious streams of glassy lava, which, in the admirable engravings of Bory de St. Vincent's work, are seen to encrust the sloping sides of the cone at an angle of at least 35°. That great cone (fig. 11) is indeed formed almost wholly of such flows of lava, gaseous eruptions being unfrequent, and its phenomena chiefly confined to the welling-up of a very viscous and ropy lava, which in some places has formed "mamelons" or small cones 70 or 80 feet high, and rising at angles of 60° and even 80° *, just in the manner of the mud-cones of Macaluba, by the overlapping of one stream upon another lazily flowing from the same central orifice: and precisely similar are the formations of Hawaii; so also those of the Sandwich Isles, as described by Dana. In fact, there are, I believe, few, if any, volcanic districts where examples of unquestionable lava-streams consolidated at high angles are not to be found.

Professor Dana, indeed, gives a sketch of an actual bottle-shaped pillar of lava 40 feet high (see fig. 12), on the flank of Mauna Loa, formed by the welling-up of a fountain-like flow of lava in an upright column, composed of one exuding wave or jet of the viscid matter congealing over another, until the excrescence reached that height, thus showing that, under certain conditions of viscosity, lava will congeal positively *in an upright position*, or at an angle of 90° †. He adds that there are many such on the same mountain (Mauna Loa), which is itself composed of repeated similar overflows of very liquid but rapidly consolidating lava from the central vent. Other lava-cones of great size in Tahiti are described by him as evidently the product of the same kind of tranquil ebullition,—the eruptions of the Sandwich Isles being in general characterized by only a small amount of explosive fragmentary ejections, but one overflowing layer of lava covering another, and forming a cone composed almost wholly of beds inclined at an outer slope of from 20° to 40° ‡.

Support has been sought for the theory of upheaval in the circumstance that within the interior of some craters we find bulky bosses or hummocks of trachytic rock, which are supposed to have been elevated in a more or less solid state, and to have tilted up the overlying beds in an encircling annular range. Examples are offered in the craters of Astroni, the Camaldoli, Rocca Monfina, and Monta-miata, in the district of Naples, in the Caldera of Palma, and that of the Great Canary Isle, &c. There is, however, no good reason for supposing the protrusion of such masses of trachyte to have elevated the surrounding crater-walls. The felspathic lavas appear generally,

* See fig. 14, p. 531.

† In truth, the common fact of the congelation of even so perfect a liquid as water in a vertical position (as in icicles) ought to have suggested itself as a warning to M. Elie de Beaumont of the weakness of his theoretical notion that lava (a far less perfect fluid) could not congeal at a high angle of slope.

‡ U. S. Expl. Exp. i. p. 356.

though not always, to have been erupted in a less fluid or more pasty and viscous condition than the augitic lavas, and on that account to have accumulated in greater bulk, and occasionally in the shape of lumpy excrescences over or near the orifice from which they issued. The massive trachytic beds and hummocks of the Mont Dore and Cantal are striking examples of this tendency; and still better, perhaps, the trachytic domes or bell-shaped hills of the chain of Puys near Clermont. In the latter instance it is well worth remarking that each of them, to the number of five, rises either close to or actually from the crater of an *acknowledged* cone of eruption composed of mantling beds of ejected scoriæ (see figs. 13 and 16). Now, had not the composition of these cones presented such incontestable proofs of their eruptive origin—had anything in their structure offered the smallest excuse for attributing their formation to upheaval—we should undoubtedly have had them exhibited by the upheavalists as conclusive examples of craters of elevation, the surrounding beds being supposed to have been tilted up by the protrusion *en masse* of the trachytic domes that rise from their centres. But that being inadmissible; since, on the contrary, we have in them undeniable examples of bulky domes of trachytic lava, whose emission was in each case evidently accompanied or succeeded by explosive eruptions, the ejection of scoriæ, and the formation of cones and craters from their accumulation, is it not most reasonable to believe that in the other instances of Astroni, Camaldoli, Rocca Monfina, &c., the same order of events occurred, and that these cones and craters, as well as the trachytic lavas they contain, are also of the ordinary eruptive character? Indeed I can assert from my own observation that this is so as respects some of them. The Piperno of Pianura in the crater of Camaldoli is proved, by the elongated shape of its vesicular cavities and dark concretionary patches, to have flowed as a lava. The trachyte of Olibano has evidently descended as a lava the outer slope of the cone of the Solfatara, on which it may be seen to rest at a high angle in a massive bed reaching from the upper edge of the crater to the sea. In Ischia there are several trachytic lava-streams or hummocks which have been poured out of the craters of very recent-looking cones of scoriæ and pumice. In Rocca Monfina, trachytic lavas exactly similar to that of the central boss are seen to issue from three or four unquestionable parasitic crater-cones on the outside of the principal cone.

M. de Humboldt speaks uniformly of the great dome-shaped trachytic mountains of South America as mere crusts that have swelled at once like enormous hollow blisters, sometimes having burst at the summit, and in this case possessing a central crater, in other instances remaining "unopened*." But, as the greater number of these mountains are in part composed of fragmentary *pumice*, there has evidently in their instance been a great disengagement of elastic vapours within the mass of lava, and eruptive explosions accompanying their protrusion. Nor is there any feature in the appearance or structure of any of them, as described by M. de Humboldt himself,

* Kosmos, p. 224.

or by other later observers, inconsistent with the supposition that they are solid throughout, and have all originated in the usual manner by the heaping up of erupted lavas and fragmentary ejecta above their respective vents. Many of them have been seen in eruption, ejecting vast quantities of fragmentary pumice (felspathic scoriæ) and ashes, as well as currents of pumice or obsidian, similar to those of some of the most evident eruptive cones and craters, for example, of Lipari, Volcano, and Volcanello. Others seem likewise to have given birth to radiating streams of trachytic lava, which, on cooling, have outwardly split into massive incoherent blocks. These streams are called *traînées de blocs* by Humboldt and Boussingault, and are considered by them to have been erupted in this disaggregated condition from fissures* ; but it would be more in accordance with the analogy of ordinary volcanic phenomena to look upon them as true lava-currents. Many of the felspathic streams of the Monts Dôme and Velay, and indeed of Etna, Vesuvius, and Hecla† likewise, and some of the basalts of the Siebengebirge, consist superficially of a chaos of apparent fragments—heaps of loose cuboidal blocks, evidently resulting from a divisionary shrinkage and fissuring of the superficial lava on exposure to the air, from the rapid escape of the disseminated vapour to which in great part it owed its imperfect fluidity.

In extreme cases this splitting into loose blocks on consolidation has been carried to so great a depth from the surface that, in the absence of actual cliff-sections, they seem to constitute the entire mass, especially towards the sides and termination of the current; and as they were, no doubt, in motion, tumbling over one another, as the lava flowed on, they will necessarily bear the appearance in such situations of a stream of fragments (*traînée de blocs*). M. de Humboldt's idea of their having been erupted in this fragmentary form is quite imaginary; and M. Boussingault's notion of earthquakes being caused by the rattling of such loose blocks in the interior of mountains‡ (like dice in a caster) is still more far-fetched and untenable. Professor Dana describes the greater number of lava-fields in Hawaii as composed of such loose angular blocks of all shapes, and of sizes from that of a half-bushel measure to that of a house, possessing a surface of horrible roughness. He calls them "Clinker-fields," and attributes their peculiar character to the lava-stream having been broken up during consolidation of the surface by a fresh moving impulse §. Such too, for the most part, are the lavas which fill the Caldera of Teneriffe, as may be seen in the photographic views of Professor Piazzi Smyth's recent volume.

Others of the trachytic domes of the Cordilleras (the "unopened domes or bells" of M. de Humboldt) probably swelled up in pasty or viscous masses above their vents of eruption, like the Puy de Dôme and its associated bosses. The idea of their being hollow, and having risen like a blister, is not supported by anything known of their structure, nor, as I have already shown, by the example of any

* Kosmos, iv. pp. 310–318.
† See Bunsen's 'Iceland'.
‡ Kosmos, iv., note to p. 170.
§ U. S. Expl. Exp. i. p. 162.

Fig. 14.—*The "Mamelon Centrale;" a boss of vitreous lava on the summit of the Volcano of Bourbon.* (After Bory de St. Vincent.)

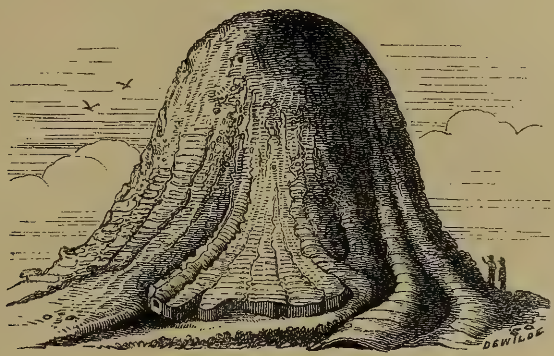


Fig. 15.—*Ideal section of the Mamelon Centrale.*

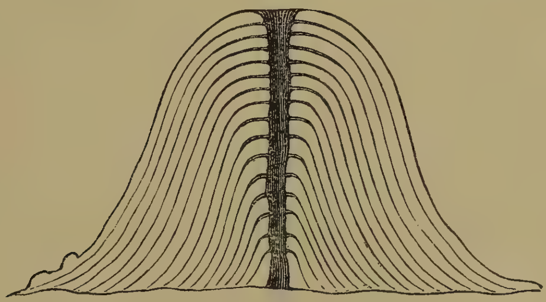
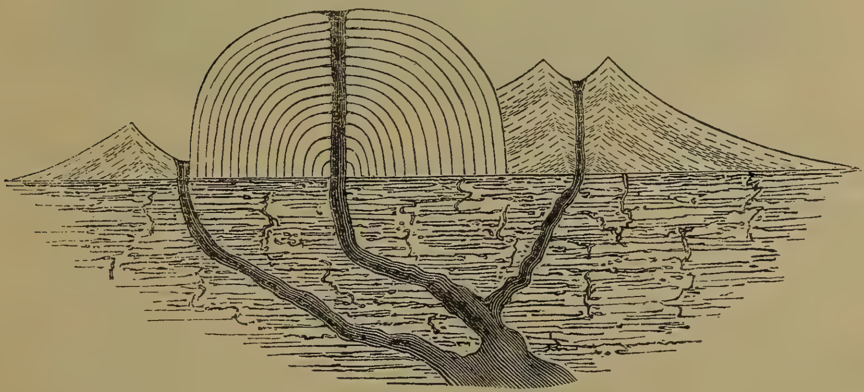


Fig. 16.—*Ideal section of the Puys de Sarcouy and Goule, Monts de Dôme* (fig. 13).



observed phenomenon of the kind. The small hummocks or *mamelons* of glassy felspathic lava upon the summit of the volcano of Bourbon, which Bory de St. Vincent watched and drew, in actual process of formation by the welling-up of an enduring source of highly viscous matter at a white heat, which consolidated as it trickled down the slope of the hill in concentric coatings, are, in all probability, types of the mode of production of all the larger trachytic bosses. (See figs. 14 and 15.) In the galleries excavated by the Romans in the flanks of the Puy de Sarcouy in Auvergne, I observed indications of such a structure in concentric coats like those of an onion. (See fig. 16.)

The cones formed by the *mud-volcanos* of Macaluba in Sicily, and of Beila near the Indus, are apt illustrations, as has been already suggested, of the probable mode of production of the bell-shaped domes of trachyte. They are, of course, solid unless where a crater has been left on the summit, but must, from the way in which they have been formed by the overflow of one coat of mud over another, be composed of concentric though irregular quaquaversal beds or layers. The accompanying woodcut (fig. 17), copied from Bory de St. Vincent, of the summit of one of the Mamelons of Bourbon erupting its viscous and glassy lava, well exhibits this analogy.

Fig. 17.—*Summit of one of the Mamelons of Bourbon, in eruption.* (After Bory de St. Vincent.)


Where lavas of this imperfect liquidity were emitted simultaneously from several contiguous orifices on the same fissure, the resulting hummocks will have been compounded into a bulky ridge with more or less of an anticlinal structure, or a string of domes, such as are not unfrequently observable in trachytic formations*.

* On reference to my volume on 'Volcanos' (1825), it will be seen that at that date I published this same view almost *totidem verbis* (p. 96), which M. de Humboldt has since appeared inclined to adopt in reference to the great chains of trachyte in the Cordilleras (Kosmos, iv. pp. 289 & 307, English ed. 1858),—a view, however, which is evidently quite inconsistent with the theory of upheaval, as I had remarked in p. 93 of the same volume.

MM. E. de Beaumont and Dufrénoy have applied their upheaval-theory to the great volcanic mountains of Central France, the Mont Dore, Cantal, and Mezen. Being well acquainted with these districts, which I have revisited in each of the last two years, and re-examined specially with a view to this question, I will venture to assert that the theory is as little justified by the facts, or rather is as inconsistent with them, in these instances, as in those of Teneriffe, Etna, or Vesuvius. We have presented to us in that district the results of a series of subaërial eruptions continued at intervals, from a great many different vents, through several geological periods, commencing with the Lower Miocene, and reaching far into the recent, probably into the human, era. No clear line can be drawn between them in respect to age, separating the ancient from the modern rocks, upon grounds of mineral character or constitution. It is from their aspect and position only, that is to say, from the more or less of denudation and decomposition they have evidently suffered through atmospheric agency, that their relative ages are determinable. But these characters of either kind are strongly marked and strikingly demonstrative, and moreover correspond together in the most remarkable and unmistakeable manner. The fresh-looking lava-streams that take their rise from perfect cones of loose red scoriæ and lapilli, and whose scoriform surfaces scarcely admit as yet of a scanty vegetation, occupy the lowest levels, and for the most part the bottoms of the existing valleys; while the elongated sheets of basalt or trachyte, whose scoriæ have either almost disappeared, or been converted into argillaceous boles, or tuffs stratified by water, appear as high platforms crowning the summits of hills. Still the *average angles of inclination of both classes of lavas are the same.* Indeed it is common to see a bed of recent lava filling up the bottom of a narrow valley through a course of many miles, while the heights on either side, several hundred feet above it, are crowned by parallel plateaux of basalt, descending with the same inclination, or gradient, in the same direction, from the same heights whence all have evidently been erupted. Now this fact is of course completely in accordance with the supposition that all derive their inclination simply from having flowed, as lavas, down the surface-slopes on which they rest, the different levels of contiguous streams being due to the successive excavation of the valleys occupied by the more recent lavas in the interval between their eruption and that of the adjoining older and higher-placed sheets of basalt. If, however, we are to believe that the latter owe their inclined position to upheaval (which is the doctrine of MM. de Beaumont and Dufrénoy), it seems impossible to account for the constant uniformity of their slope with that of the parallel lavas which are admitted by these geologists to owe their inclination to fluidity alone. There is, moreover, no line of separation to be drawn between the supposed two classes.

Nor is there, in this case, room for even the argument (worthless as it is) drawn by the upheavalists in other instances from the supposed impossibility of lavas consolidating in thick beds at a high angle of elevation; for the slopes of the Mont Dore and Cantal, composed of beds of trachyte and basalt, alternating with their conglomerates, show angles of elevation of only from about 4° towards the base, to 8° near the summits, of these mountain masses. But this is likewise just about the average angle of descent of the recent lava-streams of the Puys. The latter, by the admission of De Beaumont and Dufrénoy, owe their slope to fluidity alone. If, as these same authorities contend, the former owe their inclination to sudden upheaval alone, having been previously horizontal, surely the coincidence of the average angles of inclination of the two classes of lavas (which, too, are often placed side by side, and slope in the same direction, only at different heights, for considerable distances from their several eruptive vents) would be miraculous! That such identical effects can have proceeded from such opposite causes in so many contiguous instances is wholly incredible; and the supposition is contrary to the laws of philosophical reasoning. Besides, why do we not find the upheaved lava-beds at angles of 50°, 70°, or 90°? why not vertical? Why do they always affect just that moderate amount of angular elevation, neither more nor less, that is characteristic of the lavas which have admittedly flowed in the open air, and close to them, only from more recently-opened vents of eruption? A direct proof, indeed, that the old basaltic beds which cover the slopes of the Mont Dore and Cantal have flowed down them as lavas, is found in the fact that they are all traceable up to some high point where more or less of scoriæ and bombs show that the current of lava had its eruptive source.

Without following this branch of the subject into further detail, for which there is no space here—nor, as I conceive, any need—I may say, in a word, that, interpreted by the ordinary laws of volcanic action, the history of the volcanic remains of Central France is clear and intelligible—the Mont Dore, Cantal, and Mezen being in this view the skeletons of three great eruptive volcanos, like Etna or Teneriffe, which have been subjected to a vast amount of atmospheric degradation since the extinction of their central fires, and perhaps have shared to some extent in a general elevation of the whole district; while from numerous independent vents, along or near the same N. and S. line of presumed subterranean fissure, other single eruptions from time to time took place, resembling those of Lanzarote and the other chains of minor volcanos so often seen in the vicinity of great volcanic mountains. On the contrary hypothesis, that these mountains were severally produced by sudden upheaval, while the cones and currents of the independent vents, or at least of the more recent among them, were simply eruptive, which is the theory of MM. de Beaumont and Dufrénoy, the history of this district becomes an unintelligible chaos, as wholly irreconcileable with its visible phenomena as the theory itself is with the normal processes of volcanic energy witnessed in localities where it is still in activity.

It is satisfactory to know that M. Constant Prévost and M. Cordier, both of whom at first had countenanced the upheaval doctrine in reference to the extinct volcanos of Central France, wholly renounced and discarded the idea after visiting and carefully examining the more recently active volcanic districts of Italy. MM. Virlet and Hoffman also joined in this recantation, so honourable to these geologists.

*Craters.*—I have hitherto confined my remarks almost entirely to the upheaval-theory as it bears upon the mode of formation of volcanic cones or mountains. There remains something to be said upon the idea which it involves as to the generation of volcanic craters.

Craters are perhaps the most characteristic features of volcanic districts; they are met with of all dimensions, from the slight saucer-like depressions at the summit or on the flank of a cone of scoriæ, to the wide and often deep caldron circled by more or less sloping or precipitous banks, and the broken range of concentrically disposed cliffs, the remaining segments of what was once probably a complete circular or elliptical basin of vast horizontal extent. All, however, are alike designated as volcanic craters by geologists of every school, the only dispute being confined to their mode of origin. The upheavalists look upon them all, I believe without exception, and whatever their size or shape, as the contemporaneous result of that process to which they attribute the elevation of the heights which surround them, viz. the single, sudden, and violent outbreak of a great volume of vapour from beneath the surface. They compare the phenomenon to the explosion of a mine, or the bursting of an enormous subterranean bubble or blister, which, swelling upward, first upheaves the overlying strata, then opens at its apex, leaving them tilted around the fractured edges of the cavity. These are, indeed, the precise words of M. de Humboldt, which I quoted in the early portion of this paper. This theory seems necessarily to involve, particularly in the case of the larger craters, the notion of the subsidence or *foundering* of the central parts of the upheaved mass into the gulf so opened. M. Dufrénoy expressly attributes to subsidence of this kind after explosion, the small craters of the parasitic cones of Vesuvius, which are in his view bell-shaped bubbles that have burst at the apex. So, too, M. de Beaumont refers the formation of the great crater of the Val del Bove in Etna to the foundering of the roof or crust of the colossal bubble whose sudden upheaval created Etna, and whose bursting, he says, must have been to any modern eruption what the blowing-up of a powder-magazine is in comparison with the firing of a pistol*.

I will not repeat here the argument already referred to, that any such single explosive shock could not possibly tilt up solid strata in an unbroken ring, which is the form of the greater number of craters. I content myself with declaring my conviction that such a phenomenon as is here assumed as the origin of every crater is a pure imagination, nothing like it having ever been witnessed by credible observers, and is, indeed, wholly different from what is observed whenever and wherever a great volcanic eruption takes place and a crater is produced by it.

* P. 192, Mémoire, &c., Mt. Etna.

We do not hear in such cases (or indeed in any) of one single explosion like that of a mine, or the bursting of a bubble, followed by the engulfment of the shattered rocks, and immediate quiescence. I know of no reliable report from any quarter, or at any period, of an eruption of such an ephemeral character*. The explosive discharges of vapour having once begun, are always *continuous*, for days, weeks, months, or even occasionally for years, evidently proceeding from a mass of subterranean lava in a state of ebullition, which, having once forced a communication with the open air, at the weakest point of some fissure broken by its expansive efforts through the overlying rocks, *blows itself out* through this opening by degrees, although with terrific violence,—just as would the boiler of a high-pressure steam-engine, of enormous dimensions and infinite lateral strength, when the valve of the steam-pipe, or an accidental crack were opened—and *not* after the manner of a *boiler bursting, and discharging all its steam* at once, or of *an exploding mine of gunpowder*.

It is not by one explosion, but by the continued repetition of multiplied explosions or *eructations*, caused by the successive upward rush and discharge of innumerable vapour-bubbles of prodigious elastic tension, that an eruption is characterized, and it is by their continued action that the solid mass of rock overlying and obstructing the vent is—not at one shock, but by degrees—broken up and ejected; many of the fragments falling back repeatedly into the cavity, and being re-ejected, until they are for the most part ground by friction into lapilli (*i. e.* small globular or bouldered scoriæ), or even to the finest powder, which the winds carry to vast distances. *This* process it is that, as it were, eviscerates the mountain, leaving at the close of the eruption, when the ebullition has spent its force, that circular or oval chasm surrounded by a ring of steep sloping sides, or precipitous cliffs, which is the well-known usual form of the larger volcanic craters, and which will be generally of a size proportioned to the violence and duration of the eruption—certainly to the amount of fragmentary matter thrown out by it and spread over the surrounding slopes, or the adjoining surfaces of sea or land.

I may perhaps, myself, entertain a more distinct conception than many others, of the mode of formation of a great volcanic crater, from having enjoyed the good fortune of witnessing, indeed of closely observing, throughout its progress, the most violent eruption that has occurred in Europe within the memory of living men—I mean that of Vesuvius in October 1822, when continuous and rapid explosions (too rapid to be counted), and throwing up a column of

* The examples usually quoted of such a supposed phenomenon are those of Carguairazo in 1698, Papandayang in 1772, and Galongoon in 1822. In each of these cases, no doubt, there is ample testimony to the fact that the top of the mountain was destroyed by the eruption, and a vast chasm produced in its place. But the explosions which effected this were not single, like that of a mine, and consequently followed by subsidence of the mountain-top into some subterranean hollow, but lasted for months, and the materials of the mountain-top were blown outwards, and spread over the adjoining regions in prodigious quantities and to a vast distance.

scoriæ and fragmentary matter several thousand feet high, lasted for a period of twenty days, and were found at the end of that time to have drilled through the previous solid core of the mountain an abrupt circular chasm or caldron three miles in circumference and more than 1000 (some observers estimated it at 2000) feet in depth.

The mass of matter removed from this cavity, together with a large portion of the former external summit of the cone (which was found to have lost above 600 feet in height after the eruption), had been blown into the air. The eructations consisted of continued discharges of aqueous vapour—in fact, of *steam*, which rose to a still greater height than the fountain of solid matters (at least 10,000 feet), in a pillar composed to appearance of distinct globular volumes or puffs of steam, which, driven upwards with immense force, rolled over and over one another, looking like so many great balls of cotton, and spread laterally in some degree, as the resistance of the atmosphere checked the velocity of their ascent, while fresh discharges pressed upon them, rushing up from the vent beneath. Each puff or globe of vapour evidently consisted of the contents of a great bubble which had risen up through the molten lava in the chimney of the volcano and burst on reaching its surface. It was exactly as if a continuous succession of discharges took place from some colossal Perkins's steam-mortar in the axis of the mountain. And to the equal pressure in all directions of the enormous expansive force of these flashes of steam was owing, of course, the circular section of the crater, or canal of discharge, gradually bored by this giant artillery through the heart of the cone,—continuous discharges taking place from greater and greater depths, as the surface of the ebullient lava fell within the vent. By degrees, however, the explosions diminished in force and frequency, until at length the tension of the vapour-bubbles bursting at the bottom of the crater seemed no longer to have power to throw off beyond its encircling rim the fragments which fell within it, and the accumulation of which at length wholly stifled the explosions, and the eruption terminated. *That* is what I witnessed in 1822; and it is *thus*, I believe, that volcanic craters of large size are always formed—*not* by any *single* mine-like explosion, such as the upheavalists have imagined.

The mass of fragmentary matter thrown up during the eruption was for the most part triturated, by repeated ejection, into fine ashes, which were carried by the wind to great distances, or washed down the sides of the mountain in streams of mud by the torrents of rain that followed the eruption. On the flanks of the cone itself, the coarser scoriæ and fragments accumulated of course in great abundance. Several of the ejected masses which fell towards Ottaiano on the eastern slope measured 25 feet or more in circumference, and weighed several tons; but the average depth of the fragmentary matter spread by this eruption over the entire area of the mountain, or within a radius of some five miles, did not exceed a foot or two. At Naples, distant fifteen miles, the ashes fell to a depth of only about half an inch, although the wind drove them in that direction; and from this observation I was led to reflect on the far vaster dimensions likely to be exhibited by the craters formed in other volcanic districts by eruptions of a still more violent and tremendous character, of which well-authenticated reports have from time to time been received. Take, for example, the eruption of Coseguina in the Gulf of Fonseca in Central America, in 1835, whose ashes were thickly scattered to distances of 700 miles, while within a radius of 25 miles the ground was covered by its dejections to the depth of more than ten feet, houses and woods being buried in them! —or that of Sangay in the Cordillera of S. America (1842–43), whose black ejected ashes covered the surrounding country to a distance of twelve miles, in beds 300 and 400 feet thick (Sebastian Wiss);—or that of Tunguragua, another volcano of Quito, whose eruptions in 1797, of mud, *i. e.* of ashes mixed with melted snow or the contents of a crater-lake, filled valleys many miles in length and 1000 feet wide to the depth of 600 feet!—or that of L'Altar, another volcano of Quito, which eruption, before the discovery of America, is said by M. Boussingault to have lasted eight years, and to have covered an extensive plain with the fragments of what was previously a vast trachytic cone, higher than Chimborazo;—or that of Tomboro in the Island of Sumbawa, which in 1815, for four months continuously, threw up scoriæ and ashes in such abundance that they broke down the roofs of houses *forty miles* distant, and were carried more than 300 miles in sufficient quantity to completely darken the air at that distance, while the floating cinders to the westward of Sumatra formed a mass 2 feet thick, many miles in extent, through which ships with difficulty forced their way*. Let any one ask himself what *must* be the size of the hollows (*i. e.* the craters) left by the forcible expulsion of these startling quantities of matter from the centre of a volcanic mountain, and he will, I think, have no difficulty in perceiving that the dimensions of the largest known craters—say of three, five, or even more miles in diameter—craters such as the external "rings" of Santorini, St. Jago, the Mauritius, and others,—are no greater than what we should expect to result from such a process, which is the evacuation and outward dispersion, in fact, of the whole central mass of each mountain, and that the occasional occurrence of eruptions of stupendous violence and productive of such vast amounts of ejected matters being an undisputed fact, we have no need to resort to the supposition of either the circular upheaval of previously horizontal beds, or the subsidence or engulfment of mountain-tops (the *effondrement* of French geologists), to account for the production of these and similar craters. Of course where such craters have been exposed to the action of the sea-waves and currents, as in volcanic islands, or of torrents of water proceeding from the sudden melting of a covering of snow, perhaps of internal glaciers, they may have been enlarged by degradation, as Sir C. Lyell supposes†; but I am here discussing their original formation.

The great paroxysmal eruption of Vesuvius in the year 79 was clearly of this tremendously explosive character. It is singular that

* Lyell, Principles, p. 464, &c.

† Quart. Journ. Geol. Soc. vi. p. 207.

M. de Buch, who supposes the entire cone of Vesuvius to have been bodily *upheaved* at that time, should not have perceived that all the phenomena reported by Pliny the younger to have been witnessed on that occasion, and all such of its undoubted results as are to be seen at the present day, are of the very opposite character to those which would accompany or follow the upheaval of flexible strata in a hollow protuberance. The loud and long-continued explosions, the lofty "pine" of vapour that rose from the mountain, the dense cloud of ashes that darkened the air, the fountain of stones and lapilli ejected for many days, in such prodigious abundance as entirely to bury three populous cities under from 15 to 150 feet of accumulated dejections, are all phenomena indicative of violent eruption, not at all of upheaval. It seems clear that the southern half of the old crater's periphery was on this occasion blown into the air, and it is to the ejections of this eruption that are owing, in all probability, the thick beds of loose tuff, or pumice-ash, which mantle round the outer slopes of Somma, and indeed rise to a considerable height upon them, in some places having evidently filled up vast hollows or ravines that previously existed there. There is no reason to believe these tuffs to be marine alluvia, as M. Dufrénoy terms them. They are undistinguishable in character from and continuous with those that cover Herculaneum and Stabiæ, as Sir William Hamilton long since observed. Even at the distance of Naples there is reason to believe that the ejected ashes of this eruption fell to the thickness of several feet. In a section behind the Studii in that town, I observed a deposit of stratified pumice and lapilli, from 6 to 10 feet thick, overlying made ground in which were numerous tombs and other remains of the Greek and Roman eras, which deposit was probably formed at the period of the eruption of 79*.

The vast abundance of fragmentary matter ejected from the volcano on that occasion must (as I remarked in the paper read to the Society in March 1827) have left a proportionate cavity in the mountain; and considering that the analogous, but very minor explosions of 1822, which completely gutted the cone of Vesuvius, leaving a crater a mile in diameter, only covered the base of the mountain with a depth of ashes averaging a foot, while at Naples it was but half an inch, it is reasonable to suppose that the crater produced by the eruption of 79 must have been greater than that of 1822, in the proportion of the greater mass of ejected fragments; and the size of that of Somma, which measures about three miles in diameter, is rather within than beyond what we might anticipate from this consideration to have been formed by the eruption of 79.

The idea, indeed, of the foundering of the summit of a volcanic mountain, by the subsidence into some vast empty gulf below of what was but a hollow crust or roof, is opposed to the characteristic phenomena of volcanic eruptions, which are inconsistent with the existence of any such internal void immediately beneath such a mountain. They seem to attest, on the contrary, an overflowing

* See plate to Geol. Trans. ser. 2. vol. ii. part iii. p. 341.

abundance and excess of matter there, solid, no less than fluid and gaseous, that struggles to find a vent, and having obtained one, the mountain continues to discharge the redundant contents of its interior until the plethora is reduced, and the forces of repression, consisting in the weight and tenacity of the overlying mass (together with the weight of the atmosphere, which should not be overlooked), recover their ascendency and stop any further evacuation. This is a state of things the very reverse of that imagined by the upheavalists, namely a great internal void capable of swallowing up at one shock the whole upper crust of the mountain.

No doubt, whenever a deep crater has been formed within the axis of a mountain by some paroxysmal eruption, surrounded by vertical cliffs or fractured rock (the hollowed shell or lateral crust, as it were, of the eviscerated cone), the occurrence of a violent earthquake-shock may shake down great part of this fragile enclosure and cause it to be precipitated into the depths of the crater, by which fall the cone will lose a proportion of its height, and the crater itself be widened and partially filled. Such an event seems to have occurred on Vesuvius in 1761, according to Hamilton; but such an occurrence in no degree corresponds to the engulfment of an upheaved dome imagined by the upheavalists.

It is also not improbable that some of the small *pit*- or lake-craters, such as the Cisterna on the Piano del Lago near the summit of Etna, the *Maare* of the Eifel, and the Lacs Pavin, Thavana, and others in Central France, on whose borders are found but a very slight sprinkling of scoriæ, volcanic bombs, and other fragmentary ejecta, may owe their origin to violent explosions of very short continuance, proceeding from a local accumulation of vapour, upon the discharge of which the bulk of the overlying beds may have fallen back into the cavity left by the explosions. Many of these small craters were evidently broken through pre-existing rocks—granite, clay-slate, basalt, or other, the fragments of which are scattered around; but in no case that I am aware of is there any sign of the tilting, elevation, or even the derangement of the bedding of these rocks immediately around the craters—certainly no appearance of their conoidal or dome-like upheaval. What scoriæ or other fragmentary dejections occur about such craters are arranged in quaquaversal taluses, as usual, but quite unconformably to the old rocks through which the eruption broke out, which clearly retain their former position, whatever it was, around the cavity forcibly drilled through them. Nor, indeed, could this class of craters lend any support to the views of the upheavalists, since they admit them to be of eruptive origin*.

Another kind of pit-crater is that which occurs in several instances in the Sandwich Islands, and of which Kilauea is the best example. Where a cone has been formed by the repeated overflow of a highly liquid lava boiling up from a central vent, should its flanks at any time give way to the hydrostatic pressure of the internal column, or other cause, and a fissure be formed through which the interior is, as it were, tapped of the greater part of its contents, a circular

* Humboldt, Kosmos, iv. p. 230.

or elliptical cavity is formed by the subsidence of the fluid, surrounded by perpendicular cliffs, in which perhaps several shelves may appear, to attest the different stages of this process. This again, however, is evidently a process wholly distinct from, and even the reverse of, "upheaval*."

*Concentric Craters.*—One of the most remarkable and interesting features of volcanic craters is their frequent occurrence one within the other, in more or less concentric circles. In my former paper (of April 1856) I referred to the recorded history of the eruptions of Vesuvius during the last hundred years, and showed that within that short period the cone had been no less than five times gutted by explosions of paroxysmal violence, and the craters so formed been subsequently as often filled again by the welling up of fresh lava and the ejection of scoriæ from the bottom in the intervals of these paroxysms. And I called the attention of geologists (an attention I again solicit, since it is a point of special importance) to this alternate filling, emptying, re-filling, and re-emptying of the central crater of a volcano, as a normal process or *general law* of volcanic action, to which is owing the so frequent appearance in volcanic districts of one or more cones and craters within encircling annular cliff-ranges, or portions of such ranges—the "basal wrecks" (as Mr. Darwin justly calls them) of still larger cones formerly existing there, and blown up by some early eruptive paroxysms. As some of the most remarkable and best-known examples may be mentioned, in addition to Vesuvius and Somma (fig. 18, p. 542), those of Santorini in the Grecian Archipelago, of Barren Island in the Bay of Bengal, of Bromo in Java, as described by Professor Jukes, St. Helena, St. Jago (well described by Mr. Darwin), the Pic de Fogo in the Cape de Verde Islands, the Cirque of Teneriffe (fig. 4) (within which rise the cones of the Peak and Chahorra), the Curral of Madeira, the Cliff-range around the volcano of Bourbon (fig. 19), Antuco in Chili, Irasu in Costa Rica, the Campo Bianco, and the Isle of Volcano in the Lipari Isles (figs. 20 and 21), and many others. The outer rings in all these instances, as well as the interior cones and craters in nearly all, are of course considered by the upheavalists as "elevation-", or "upheaval-craters;" but only because, as I think I have shown, they have no correct conception of the character of the eruptions which give rise to such, or indeed to any craters.

It is, in truth, singular how completely this theory has blinded its advocates to the best-attested facts respecting even that trite and most frequented of European volcanos, Vesuvius, which is within view of the luxurious residences of Naples, and which consequently has been visited and explored more than any other. They appear

* Professor Dana thinks that there is no limit to the size of craters formed in this mode, and considers that those of the moon may be pits of the kind. But the moon-craters are not encircled by abrupt precipices; they rather resemble, in aspect and configuration, the tuff-craters of the Phlegræan Fields, which owe their origin to explosive subaqueous eruptions in shallow water. The remark, however, is suggestive of the important bearing of the theory of the formation of cones and craters upon astronomical no less than on geological questions.

Fig. 18.—*View of Vesuvius from near Sorrento.*

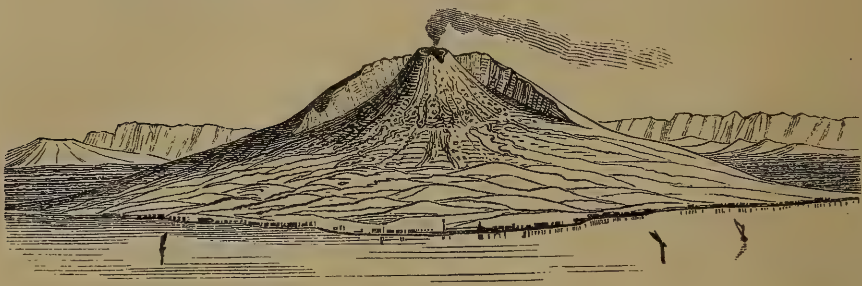


Fig. 19.—*The Volcano of Bourbon, seen from the old cliff-range nearly surrounding it.* (After Bory de St. Vincent.)


Fig. 20.—*View of Volcano and Volcanello, Lipari Isles.*

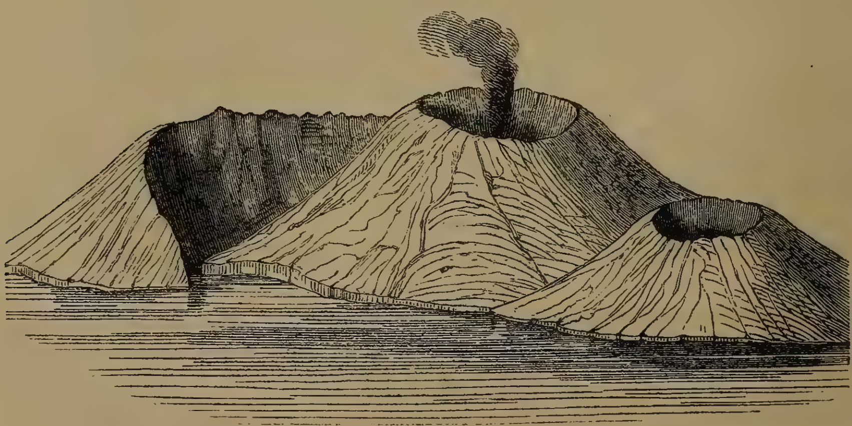


Fig. 21.—*Plan of Volcano and Volcanello.*

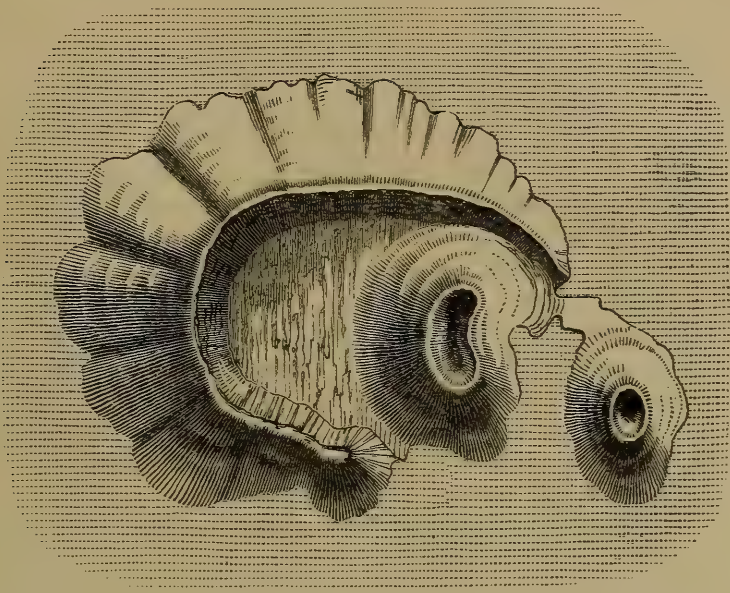
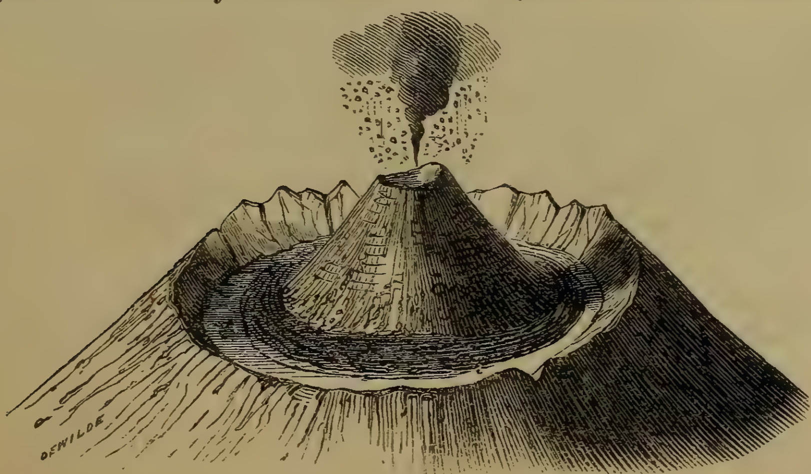


Fig. 22.—*Summit of Vesuvius in* 1774, *showing cone within cone.* (From Sir W. Hamilton's 'Campi Phlegræi.')

Fig. 23.—*Summit of Vesuvius in* 1777. (After Sir W. Hamilton.)



to give no credit to the well-attested frequent and great changes of form in the cone and crater of that mountain, many even within memory of man, and to which I have already referred—changes, the earlier of which are admirably delineated and described in the great work of Sir William Hamilton, who himself witnessed many of them between 1768 and 1800, during which long period of thirty-two years he resided at Naples and continually watched the volcano (see figs. 22 and 23). Coming to a later period, the upheavalists do not seem to be aware that for some years previous to 1822 Vesuvius had no crater at all, but showed on its truncated summit a rough platform upon which several parasitic cones were occasionally thrown up, and subsequently destroyed by minor eruptions, while streams of lava flowed from them almost continually down the slope of the cone and hardened there. They do not seem at all aware that the explosions of 1822 blew off the summit of the cone with all its excrescences, lowering its absolute height by some 600 or 800 feet *, and replacing the solid platform by a crater a mile in diameter and a thousand feet deep, which vast cavity was within a very few years filled again by subsequent eruptions from the bottom, and has been again nearly emptied and re-filled in a similar manner more than once †. (See fig. 24.) In the face of these well-known facts we have M. de Humboldt endorsing the strange dictum of de Buch, that Vesuvius has not changed at all in height or

Fig. 24.—*Ideal Section of Vesuvius and Somma before and after the eruption of* 1822.

The fainter lines represent the portion removed by the eruption.

bulk since the year 79 of our era; and gravely attributing recorded differences in its height either to incorrect measurements only, or internal elevation *en masse*—that is, renewed upheaval of the entire cone ‡.

It is singular that the geologists of the last century, Hamilton, Breislak, and Spallanzani, should have held views respecting the action of volcanos so much more accordant with the truth than

* Reducing it from 4200 feet to 3400 feet above the sea.—Forbes.
† See my paper on Craters, &c., Proc. of Geol. Soc. vol. xiv. p. 335.
‡ Humboldt, Tableaux de la Nature: Paris, 1829. Kosmos, iv. p. 346.

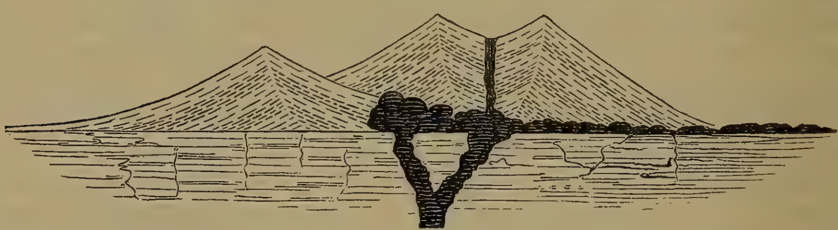
authorities so eminent in the present day as MM. de Humboldt, de Buch, de Beaumont, and Dufrénoy.

To recapitulate. My argument then is, that the "elevation-crater" or "upheaval" theory, as applied to volcanic action by MM. de Humboldt, de Buch, de Beaumont, and Dufrénoy, and to some extent by Dr. Daubeny and Professor James Forbes, as well as in several popular geological compilations, is an assumption irreconcileable with the appearances it professes to account for, and wholly hypothetical—such a process never having been witnessed; while there is nothing in the form, structure, or composition of any of the cones or craters to which it is applied by its advocates inconsistent with the supposition that they owe their origin to the simple, ordinary, normal, and perfectly intelligible phenomena of volcanic eruptions, as witnessed repeatedly by competent observers as well in the present day as through all past historical times.

Such eruptions, where they break out on new points of the surface, are seen to throw up large quantities of scoriæ, fragmentary blocks, and ashes, which accumulate (as they fall) into conical hills, having generally a circular depression in the centre or at the summit, the cause of which I have already explained. The component layers of these hills have always, and, from their mode of formation, necessarily, a quaquaversal outward dip, and occasionally also a double or anticlinal concentric arrangement. And the same disposition of the fragmentary ejectamenta is likely to take place, and appears in fact to have taken place, when the eruption was submarine as when it was subaërial, except so far as the weight and resistance of the water above, or the wash of waves or currents, have modified it. The lavas simultaneously protruded during such eruptions take a course determined by their fluidity and specific gravity and the form of the neighbouring surfaces:—where their fluidity and specific gravity are both considerable, as in the fine-grained basaltic lavas, and the adjoining surface-levels favourable, spreading widely, or flowing to great distances, in comparatively shallow sheets or streams; where the fluidity is less, accumulating in thicker beds in the vicinity of the orifice of eruption; where it is at the *minimum* (as in the case of the highly vitreous and consequently viscous, or the spongy and porous trachytes), heaping itself up above the vent in bosses, hummocks, or dome-shaped masses, just as any very viscid liquid in ebullition, like paste or pudding, will coagulate in lumpy excrescences above any crevice in the containing vessel through which it can force a partial escape.

Where eruptions habitually or frequently take place from the same vent, it is obvious how the repetition of such a process as has been described in the case of single eruptions must cause the formation of a mountainous excrescence, approaching to a conical form, composed of the accumulated products, both fragmentary and solid, arranged more or less irregularly (according as they may be subjected during, or in the intervals of, the eruptions to more or less of atmospheric, or in some cases marine, degradation), and of a bulk and dimensions determined by the comparative fluidity of the expelled lavas and the comparative abundance and character of the fragmentary ejections. When, as often is the case, owing to the obstruction of the central vent, eruptions, whether of lava, or of scoriæ alone, or of both together, have occurred repeatedly on the lower flanks or near the base of the volcanic mountain, its form will have been proportionately varied, by the greater bulk added to its lower as compared with its higher slopes. Often some great paroxysmal eruption will have broken a huge crater through the core of the mountain thus formed, blowing off its summit and fairly emptying its bowels, leaving a truncated cone, perhaps only a "basal wreck," like the roots of a hollow tree-stump, wholly or partly encircling the cavity, which subsequent eruptions from its interior may not have been able as yet to fill up. Sometimes two or three of such encircling cones and craters will have been successively formed, one within the other, round a common centre of eruption. Occasionally the habitual vent will have been so strongly sealed up by the consolidation of the lava contained in it, or the accumulation of ejected matters above it, as to force the subsequent eruptions to shift to a new point of the same, or some newly broken, fissure; and the axial centre of the mountain will thus have changed its place, giving rise to an elliptical figure and other corresponding irregularities in the external form and also in the internal structure of the mass. The strata of the new cone will rest in such cases unconformably on those of the old, as we see is the fact in Etna. This must also be the case in the smaller cones of scoriæ, the product of a single eruption, when the position of the vent has slightly varied, as happened in the case of the Puy Pariou in Auvergne. (See fig. 25.)

Fig. 25.—*Ideal Section of the double cone of Pariou, Monts de Dôme.*



What I maintain is, that, making allowance for these several varying circumstances, all of which are within the range of admitted and indisputable experience in the instances of eruptions actually witnessed, there is nothing in the form, structure, or mineral character of any volcanic mountains or formations yet observed, which cannot be explained by the simple, intelligible, and consistent laws of volcanic action briefly described above, and that consequently there is no need for the supposition of a sudden circular upheaval of previously horizontal beds of volcanic matter to explain the mode of production of any one such mountain—far less of all, or nearly all, to which the upheavalists insist on applying their theory.

Of course it is not intended to deny—on the contrary, it is an element in the theory of volcanic action above sketched—that the central parts of a volcanic mountain will from time to time suffer a certain amount of derangement, and even of absolute elevation, in the course of its progressive accumulation,—an amount corresponding (as I said in my work on Volcanos of 1825, and again in 1827) to the number and bulk of the injected dykes that penetrate its beds being formed by the filling up with intruded lava of fissures broken through its framework by the expansive throes or local earthquakes that more or less accompany each eruption. But this "inward growth or distension" will be trifling in comparison with the increase of the mountain by outward accretion or accumulation; and that it has always been so may be seen from the proportionate bulk of the beds of lava and conglomerate, and of the dykes that traverse them, wherever the interior of a volcanic mountain has been exposed *. Above all, it must have been a *slow* and *gradual* process, accompanying, throughout, the *gradual accumulation*, in very much larger masses, of sloping beds, both solid and fragmentary, formed from the external dejections of the volcano; and therefore in no degree justifies the theory of the single, sudden, and simultaneous upheaval of such a mountain by "a bubble-shaped swelling-up of the ground"—enounced by MM. de Humboldt, de Buch, de Beaumont, and Dufrénoy, as the normal mode of formation of a volcanic mountain.

Still less is any confirmation of their doctrine to be found in the amount of elevation *en masse* of large superficial areas, upon which the products of volcanic eruptions have been previously accumulated. This no one doubts to have occurred in many instances—as, for example, the entire western coast of Italy, the submarine base of Etna, of Teneriffe †, of Madeira, and of numerous other volcanic islands or districts. It is, however, a remarkable fact, that in the interior of continents, where the greatest amount of elevation *en masse* has taken place, few or no volcanic eruptions have occurred; and contrariwise, the greater number of (indeed nearly all) volcanic districts are found in islands, or along coast-lines more or less removed from, though exhibiting remarkable parallelism to, the great neighbouring continental mountain-ranges or elevated areas—a disposition favourable to the generally received notion that volcanos act as *safety-valves*, letting off the local excess of subterranean expansive force or caloric, which, where such escape is denied, distends, dislocates, and upheaves the solid superficial rocks in masses of a much more extended area. This remark, made by me in 1825, was illustrated by a rude map of the parallel Volcanic and Plutonic ranges of the globe ‡. It has obtained the sanction of many geologists, even of MM. de Humboldt and de Buch. But I submit

* See Trans. Geol. Soc. Lond. 2nd ser. vol. ii. p. 341, 1827.

† This was, of course, the cause of the position of the marine shells found in the Isle of Teneriffe at insignificant heights above the sea-level, which are brought forward by Mr. Piazzi Smyth as a proof of the upheaval of the whole mountain. See Sir C. Lyell's notice in Phil. Mag. July 1859.

‡ Considerations on Volcanos, 1825–6.

that its truth adds another argument against their theory of the upheaval of volcanic mountains, and supports the opposite view which, in common with Mr. Darwin *, I entertain, that there is "local antagonism," rather than coincidence, between direct elevation and volcanic action,—that "dislocations on a large scale are rare in volcanic districts;" or, as M. Constant Prévost expresses it, "Les produits volcaniques n'ont que localement, et rarement même, derangé le sol à travers lequel ils se sont fait jour †."

And on all these grounds it is submitted that the theory of elevation-craters of MM. de Beaumont and Dufrénoy, the *Erhebungs-kraters* of de Buch, the "bubble-shaped swelling-up of horizontal volcanic strata" of Humboldt, as applied by them to account for the formation of volcanic mountains, is an unnecessary and untenable hypothesis, which, by introducing vagueness and uncertainty into the views hitherto generally entertained by geologists of the laws of volcanic action, offers a serious impediment to the advance of sound geology.

For let no one imagine that this question is one of minor importance, affecting the theory of volcanos only, and that it may be safely left in abeyance while the other great departments of geology are making safe and certain progress. It is a question that vitally affects the whole theory of geological dynamics. If we are to believe that such stupendous mountain-masses as Etna, Teneriffe, Chimborazo, Elburz, and the other great volcanos of the two hemispheres, were each of them elevated suddenly, and at one stroke (*d'un seul coup*, in the words of Elie de Beaumont when speaking of Etna), by the expansion of a single great bubble of elastic vapour—and that consequently they are even now mere arched crusts covering a vast hollow void or blister,—of course such a belief must largely influence the views of geologists in regard to the machinery by which the great terrestrial mountain-ranges, other than volcanic, have been elevated, and the time occupied by that process. The notion of the *sudden* and *simultaneous* upburst of the great Alpine chains of the old or new worlds from the bottoms of tertiary or secondary oceans to the vast heights which they now obtain, would, in this case, appear quite in the order of Nature, the probability of such extraordinary events being supported by the analogy of volcanic mountains. And it is obvious how the supposition that, beneath these suddenly-elevated tracts, vacuities of corresponding magnitude probably exist, must affect the theory of superficial subsidences.

On the other hand, if we come, as I believe we must, to the conclusion that volcanic mountains have been slowly built up by the gradual accumulation, layer above layer, of the products of successive intermittent eruptions from the same or contiguous vents, very slightly, if at all, affected by direct upheaval, a strong ground of analogy will be laid for the belief that the elevation of the great non-volcanic mountain-ranges of the globe, and the changes of level of the other rocks which exhibit signs of displacement, have likewise

* Volcanic Islands, p. 78. † Mém. Soc. Géol. de France, ii.

been effected gradually,—more or less, it may be, by fits and starts, such as we have an example of in earthquakes, and with occasional paroxysms, like those witnessed in volcanic eruptions—but by *progressive steps*, and not by such immense single expansive throes as are the favourite idea of M. de Beaumont and those continental geologists who maintain the theory of upheaval of volcanic cones and craters,—the one supposition being, in fact, the counterpart and fit companion to the other.

It is, at all events, certain that the fundamental conception of the chronology of our geological periods must be largely affected by these considerations. Our views as to the laws of plutonic action upon and beneath the earth's crust cannot but be influenced by those we entertain respecting volcanic action; for few geologists will doubt that both are modifications of the same subterranean agent under varying conditions. It becomes therefore the interest of every inquirer into the history of our planet that the question raised in this discussion should be closely examined, and, if possible, conclusively solved.

If, in the endeavour to perform this duty, I have appeared to treat with little reserve the authority of geologists of eminent reputation, I trust that the facts and arguments advanced in opposition to their view of the question, and the immense importance to our science of its complete and final settlement, will be my sufficient apology.

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February 18, 1859.

Annual General Meeting.

[For the Reports of the Council, &c., see the commencement of this volume.]

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February 23, 1859.

Richard Trench, Esq., Geol. Survey of Great Britain; William Francis, Ph.D., Richmond and Red Lion Court, Fleet Street; the Rev. Thomas Wilkinson Norwood, Cheltenham; John Johnes, Esq., Dolaucothy, near Llandeilo; and John Bainbridge, jun., Esq., Fishergate Villa, York, were elected Fellows.

The following communications were read:—

1. *Notice of* Lias Deposits *at* Quarry-Gill *and other places near* Carlisle. By E. W. Binney, Esq., F.R.S., F.G.S.

On the western side of the Pennine Chain, up to this time, none of the secondary rocks superior to the Trias have been noticed north of the small patch of Lias at Audlem in Cheshire; therefore the discovery of a considerable tract of Lias near Carlisle will no doubt be interesting.

For some years Mr. Richard B. Brockbank, of the firm of Messrs. Carr & Co., of Carlisle, has been diligently in search of coal, and has investigated the northern portion of Cumberland with considerable care. His attention was chiefly directed to the district lying between Curthwaite, on the Carlisle and Maryport Railway, and the Solway, especially about Aikton and Oughterby, places which Prof. Sedgwick had thought likely for finding coal, and where that eminent geologist had been informed that a coal-seam, of 16 inches in thickness, had been actually found *.

The first place where Mr. Brockbank found the "blue metals" which had always been thought to be coal-measures was in the brook at Thornby. In examining them he found a shell resembling an Ammonite, and some other fossils, which induced him to think that the beds might prove to be Lias. On his transmitting, through Mr. Brockbank, engineer, of Manchester, the specimens to me, I immediately pronounced them to be Liassic.

On the 13th January, 1859, being at Carlisle, Mr. R. B. Brockbank was so good as to drive me over the district. We first went to Moorhouse, near which place we saw the Till, of a reddish colour, exposed 12 feet without reaching its bottom. It is full of stones, mostly rounded, consisting of Criffel granite and slate and Silurian rocks, but it is nevertheless used for brickmaking. West of Moorhouse the land is on a cold clay, with considerable beds of peat on it. On passing through Oughterby, Mr. Brockbank pointed out the place at Moor Dyke where a small seam of coal is reported to have been wrought. We next went to Quarry-Gill to look at the Mountain-limestone, which had been quarried many years ago, and which he thought might indicate the position of some of the lower coals. He had found the dark shales in Thornby Brook, and, from the fossils contained in them, suspected them to be Lias; but he never imagined that Quarry-Gill stone was anything but mountain-limestone, and he quoted Prof. Sedgwick and other geologists in support of his opinion.

On my going into the field where the old quarry had been opened, I picked up a piece of limestone containing shells of *Gryphæa incurva*, which left no doubt in my mind as to the limestone being Lias. The old quarry is now filled up; but dark Lias-shales are seen *in situ* in the ditch near the well, and in the well itself the limestone is seen. The well derives its water from a bore-hole through the limestone, about 6 feet in depth, as a person who had put a rake-shaft down informed us; but in all probability it is much deeper. The walls of the well are constructed of Lias-limestone, and that rock is lying about on the surface over the field. Herewith are sent specimens, collected by me, full of *Gryphæa incurva*, *G. inflata* (?), *G. depressa* (?), an *Ostrea*, and other shells.

* See Prof. Sedgwick's paper on the Basin of the Eden and the North-western Coasts of Cumberland. Transact. Geol. Soc. 2nd ser. vol. iv. p. 383 &c.

At Fisher's-Gill Farm, a short distance from Quarry-Gill, is a well sunk through the Lias-shales into the limestone.

At Thornby Brook, south-east of Aikton, are the Lias-shales first found by Mr. Brockbank. They are seen in the brook's course, and are not exposed more than 2 feet in height and for a distance under 100 yards in length, being covered up by a thick deposit of reddish-coloured Till. In these shales are found several species of *Ammonites*, which break in pieces on being taken out of their matrix, and two or three species of bivalve shells. Ironstone-nodules containing bivalve shells also occur in the shales. The dip of the shales is difficult to determine with certainty; but at one place it appeared to me to be 23° to the W.S.W. Specimens of the fossils from Thornton Brook are sent herewith.

Mr. Robinson, an intelligent well-sinker in Kirk Bampton, informed me that in the course of his searches for water he had become well acquainted with the dark shales and limestones in which people had long been searching for coal. This he had often heard as having been found, but he had never seen it himself, and indeed never expected to do so. At Wiggonby a bore-hole had been put down 40 yards into the dark shales. At Bank House the same beds are to be seen near the surface. They have also been met with at the Flatt and Nut-Gill. At Oughterby Pastures they are seen in the water-holes which have been dug in them. At Orton Sir W. Briscoe bored in them. He thinks that they have also been met with both in Crofton and Aikton. Thus it appears, from Mr. Robinson's information, that this Lias-deposit occupies a considerable district, extending under the rising ground between Crofton and Orton, on the south, and the Solway, on the north, comprising Aikton, Thornby, Wiggonby, Oughterby, and probably other places on the rising ground between the Carlisle and Maryport and Carlisle and Port Carlisle Railways. As the country is covered up with a thick deposit of Till, and there are no natural sections, the boundaries of the Lias will be difficult to trace with certainty; but to me it appears to lie on the "Waterstones" and red marls of the Trias seen in the Eden near Carlisle, and which appear to dip in the direction of the Lias described in this short communication. It seems somewhat singular that so large an extent of Lias should have so long escaped observation; but it is no doubt owing to the district being thickly covered with Till, and affording few (if any) natural sections.

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## 2. *On the Fossils of the* Lingula-flags *or* "Zone Primordiale." By J. W. Salter, Esq., F.G.S., of the Geological Survey of Great Britain.

### *Paradoxides and Conocephalus from North America.*

The occurrence of an isolated new fossil, either at home or abroad, is seldom worth illustration in the pages of our Journal, unless, as in the present instance, it extends the range of a new or little-known formation, or has some other special geological interest.

It is now several years since M. Barrande began to lay stress on the most ancient of his Bohemian formations, and to draw strong lines of demarcation between what he called his *Faune primordiale* and all the succeeding faunæ of the Silurian series; and further investigation, either by himself or other naturalists, has only tended to confirm the distinctness of this lower zone, and to show a marked similarity in the types which characterize it wherever found.

Barrande himself was the first to point out the existence of this formation in the United States (Wisconsin, &c.), as he had before indicated it for Britain. It has since been recognized in Spain and Normandy. Some few connecting links have been discovered, to unite it with the great overlying group; but, as a whole, both in its contained species and genera, it remains a perfectly distinct and well-marked formation, incomparably more cut off from the Lower Silurian, than the latter is from the Middle or Upper portions of the same system.

Among the characteristic genera of this zone none is more conspicuous than *Paradoxides*, one of the largest forms of Trilobites, and possessing marked peculiarities of structure. Numerous species are known in Europe, but only one as yet from Britain; and until lately it was doubtful if the genus existed in America. The discovery, however, of the true locality for *Paradoxides Harlani* of Green*, which occurs in great abundance in Massachusetts, has extended the true range of the "primordial zone" to that region, and thus defined the age of those altered rocks in which it is found; for, though the genera *Olenus* and *Agnostus* (the last certainly) do range out of the Lingula-flags into the Llandeilo and Caradoc deposits, no instance is known of such transgression on the part of *Paradoxides* or of *Conocephalus*, the genera on which we have now to offer a few descriptive data.

The *Paradoxides* under notice has been lately sent from Branch, on the promontory between St. Mary's and Placentia Bays, Newfoundland; and, so far as I know, is the first Lower Palæozoic fossil discovered in the whole island. Mr. Bennett, who sent these specimens to the Bristol Institution, says that it is accompanied by many other fossils; which statement we hope to see verified shortly by a large consignment to London.

The matrix is a hard, fine-grained, flinty slate.

### PARADOXIDES BENNETTII, spec. nov. (Fig. 1.)

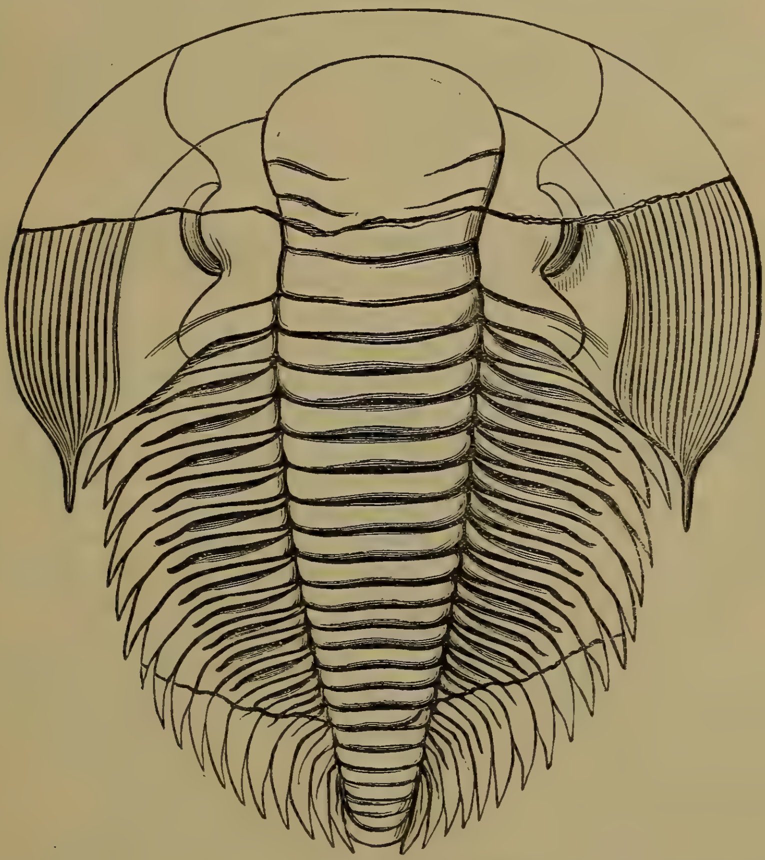
*P.* maximus; capite valdè expanso, latitudine æquante longitudini corporis, angulis in auriculas magnas productis, spinisque brevissimis: axi corporis latissimo, pleurarum apicibus foliosis, curvatis, vix reflexis. Long. et lat. 10 unc.

The largest of all known species of the genus, this *Paradoxides* is easily distinguished from the other great Trilobites, *P. spinosus*, *P.*

* At Braintree, ten miles south of Boston.—Prof. W. B. Rogers, Proc. Amer. Assoc. vol. iii. 1856, p. 315; and Boston Nat. Hist. Soc. Proceed. vol. vi. pp. 27, 40.

*Bohemicus*, &c., by the extraordinary width of the head, which is 9½ inches broad, and, so far as can be judged from the portions remaining, fully as wide as the length of the entire body. Moreover it is distinguished by the large expanded pendent ears at the posterior angles, which are suddenly terminated by a short narrow spine. The border is extremely broad, and marked with coarse remote lineations, while the ridge that separates it from the rest of the cheeks is very prominent.

Fig. 1.—*Outline-sketch of* Paradoxides Bennettii (*Salter*), *from Newfoundland.* (One-third of the natural size.)



The lighter lines indicate the parts of the outline that have been restored.

The axis of the broad thoracic segments is quite as wide as the pleuræ for the four or five front rings, and thence diminishes rapidly, in proportion to the width of the pleuræ, as far as the twelfth segment. We have only clear evidence of fifteen rings to the body; but in all probability there were seventeen, if not more. No caudal shield is known.

Although the axis is so broad, the pleuræ bear about the same proportion to it as in other species, and resemble those of *P. spinosus*, Boeck. They have the usual strong groove crossing them obliquely, and their ends are expanded, gently curved, and scarcely at all reflexed,—while those of the Bohemian species above referred to ar very much so. There is another point of resemblance in the slight expansion only of the second pair of pleuræ, the appearance being rather as if the third pair were abbreviated than as if the second were at all lengthened.

Lastly, one of the specimens shows what is rarely met with among Trilobites, namely, an injury or malformation—the sixth and seventh pleuræ on the left side being shortened by the injury.

Next I have to notice the occurrence of a very interesting fossil, brought to England by Dr. Feuchtwanger, and placed with numerous other American fossils in the Great Exhibition of 1851. It is a cast in a brown sandstone, said to be a bouldered fragment from Georgia, and as the species appears to be distinct from any previously described, there seems no reason to doubt the locality. The caudal shield and part of the body are broken away, but the greater part of the carapace, and ten body-rings remain. It is about the size of *Conocephalus striatus* from Bohemia, and may be called—

CONOCEPHALUS ANTIQUATUS, spec. nov. (Fig. 2.)

*C.* sesquiuncialis, convexus, glabellâ parabolicâ lobis inconspicuis; genis vix radiatis, oculis medianis glabellam propioribus, segmentis corporis pleuris curvatis, haud abrupte deflexis.

Head (or carapace) semicircular, convex compared with those of other species, the glabella somewhat parabolic and rounded, not truncated in front, nor much expanded below. It is convex, and the lobes are very obscure (the specimen, however, has suffered abrasion); the lower pair of lobes are rounded, the middle pair of furrows remote from these, and the upper ones, very near the anterior end, all but obliterated.

Fig. 2.—*Outline-sketch of* Conocephalus antiquatus (*Salter*). (Natural size.)

The hinder portion of the body and the right cheek have been restored.

Cheeks convex; the eye nearly midway, and about its own length from the posterior margin. Neck-furrow distinct, not very strong. Facial sutures as in *C. striatus*; the convex cheeks radiated, less conspicuously so than in that species. The ocular ridge, if any existed, must have been very slight.

The axis of the body-segments is convex and narrow, two-thirds the width of the pleuræ, which are gently convex, scarcely flat even as far as the fulcrum, and thence curved down, not abruptly bent as in *C. striatus*. The fulcrum in the forward rings is placed more than halfway out,—in the tenth about halfway, and the furrow which bisects the pleura is shallower than in either of the Bohemian species.

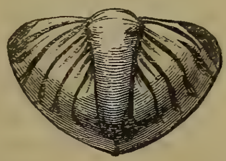
The characters which distinguish *C. antiquatus* from *C. striatus*, which most resembles it, may be briefly stated:—1. The greater convexity of the carapace, especially the glabella, which is long and rounded, not short and subtruncate; 2. The less remote eyes, and 3. The gently curved, not abruptly bent, pleuræ. The margin and head-spines are lost, but the former was probably not so thick as in *C. striatus*; while the radiation of the cheeks is far less conspicuous.

3. *Asaphus* (or *Olenus*?). (Figs. 3 & 4.)

There is a rather obscure trilobite (fig. 3) in the "Calciferous Sandrock" or "Chazy Limestone" of Grenville (Ottawa, in Canada), which Sir W. E. Logan discovered and brought to England. It may, I think, belong to the *Olenidæ*, though certainly not to *Paradoxides*, to which genus it was too hastily referred by me in Sir W. E. Logan's

Fig. 3.—*Portion of the head of an* Asaphus *or* Olenus, *from Ottawa, Canada.* (Natural size.)

Fig. 4.—*Caudal shield of an* Asaphus (?), *from Ottawa, Canada.* (Natural size.)



paper*. The great size of the curved eyes, and the obscure glabella-lobes give it much the aspect of *Proetus*, and the finely granular surface offers no contradiction to this view; but no *Proetus* is known with the glabella as wide in front as behind. It may be a new form allied to *Asaphus*, but the granular surface is an anomaly in that group. On the whole its affinities are so obscure that, until better specimens are obtained, it would be useless to give it a name; and I only figure it here to show that it does not belong to the genus to which I at first referred it, nor, so far as I can see, to any of the characteristic genera of the Primordial group.

It is not a very uncommon species. Fig. 4 shows the caudal shield associated with it, and which is like that of some *Asaphidæ*.

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3. *On a* New Species *of* Dicynodon (D. Murrayi) *from near* Colesberg, South Africa. By Professor T. H. Huxley, F.R.S., Sec.G.S.

(Abstract.)

[The publication of this Paper is deferred.]

For the original specimen from which Professor Huxley first (in the spring of last year) obtained evidence of the existence of this species, he was indebted to the Rev. H. M. White, of Andover, who subsequently put the author in communication with the discoverer of the fossil, Mr. J. A. Murray, and the latter gentleman having written to his father, resident in South Africa, obtained for Professor Huxley a large quantity of similar fossil remains. One specimen in par-

* Quart. Journ. Geol. Soc. vol. viii. p. 207, *note*.

ticular, having been carefully chiselled out by Mr. Dew, afforded a complete skull of this peculiar and previously undescribed species of *Dicynodon*.

The author described the distinctive features of this skull in detail. *Dicynodon Murrayi* is distinguished from all the already known species by the following characters:—

1. The plane of the upper and anterior face of the nasal and premaxillary bones would, if produced, cut that of the upper face of the parietals at an angle of about 90°.

2. The supratemporal fossæ are much longer from within outwards than from before backwards, owing partly to the shortness of the parietal region.

3. The alveoli of the tusks, the transverse section of which is circular, commence immediately under the nasal aperture, and extend forwards and downwards parallel with the plane of the nasal and upper part of the premaxillary bones, and do not leave their sockets until they have passed beyond the level of the posterior end of the symphysis of the lower jaw.

4. The nasal apertures are altogether in front of the orbits.

5. The length of the upper jaw in front of the nasal apertures is certainly equal to one-third, and probably to one-half, the whole length of the skull, which is between six and seven inches.

6. The os quadratum is about half as long as the skull.

These structural peculiarities are sufficient to distinguish *Dicynodon Murrayi* from all others; and the author stated that he should reserve the description of many other anatomical features, which are probably more or less common to other Dicynodons, such as the bony sclerotic, the bony interorbital septum and vomer, the characters of the humerus, of the pelvis, and of the ribs, for another paper, in which other Dicynodont remains would be considered.

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4. *On the* Coal *found by* Dr. Livingstone *at* Tete, *on the* Zambesi, South Africa. By Richard Thornton, Esq.

[Forwarded from the Foreign Office by order of Lord Malmesbury.]

(Abstract.)

Mr. Thornton states that this coal, which was dug by the natives from an outcropping seam on the bank of the River Muntizi, is free-burning; showing no tendency to cake; containing very little of either sulphur or iron, a large proportion of ash, but only a little gaseous matter. The result of the trial (made in the steam-launch) of this coal, and its appearances, favour, in the author's opinion, the idea that the coal, when taken from a deeper digging (that which Dr. Livingstone had sent was collected at the surface of the ground), will probably contain less ash and a little more gaseous matter.

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# POSTPONED PAPER.

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## *On the* Succession *of the* Rocks *on the* North Coast *of* Scotland.

By John Miller, Esq.

(Communicated by Sir R. I. Murchison, F.G.S., &c.)

[Read December 15, 1858.]

In the summer of 1841, I made a geological tour through the northern half of the county of Sutherland as far as Cape Wrath, and I returned from my trip acquiescing in the opinions which then prevailed regarding the succession of the rocks on the north coast of Scotland.

Dr. M'Culloch had described the mineralogy, succession, and relations of the rocks between Cape Wrath and the River of Hope in his usual vigorous style as early as 1819, and, considering the state of geological science at that period, with wonderful precision and correctness; but he stopped short in his researches at the point just mentioned, and left to others the task of describing the geology of the north coast continuously from the Atlantic to the German Ocean. This task was, however, accomplished by Messrs. Sedgwick and Murchison, who laid the result of their labours before this Society in 1828. In their memoir the gneiss of Cape Wrath is regarded as the base of the system; and, proceeding eastward, it was assumed that the conglomerate and red sandstone of Cape Wrath came next in the ascending order, and were the true Old Red Sandstone,—that the conglomerate and sandstone of Tongue and its neighbourhood were of the same age,—and that from Strathy Bay to the German Ocean at Duncansby Head, the Old Red Sandstone rocks of Caithness extended in three great divisions, of lower or conglomerate, middle or flag schists, and upper or newer red sandstone. Regarding the limestones of Duirness, no decided opinion was pronounced.

In 1839 Mr. Cunningham published his little work on the Geognosy of Sutherland, in which, in addition to a mass of most valuable mineralogical facts and observations of his own, he corroborated the opinions of M'Culloch regarding the succession of the rocks from Cape Wrath to the east side of Loch Erriboll; and he did more: he clearly laid down the doctrine that the great central gneiss which overlaid the limestone of Loch Erriboll and extended from that point eastward to Caithness must be regarded as a more recent gneiss than that of Cape Wrath, and that the conglomerates and sandstones of Tongue, Portskerray, and the east coast of Sutherland were also newer than the sandstones of Cape Wrath, and must rank as a distinct and more recent formation. But Mr. Cunningham's work was not written in an attractive style and did not excite much interest.

In the mean time various geologists had searched for fossils in the red sandstone of Cape Wrath and in the limestones of Duirness, as without their evidence any classification of the rocks could only be looked upon as provisional and problematical; and when I visited that country in 1841, I looked anxiously for fossils, particularly in the Duirness limestone, but without success. Nothing new was heard of the geology of the district until Hugh Miller paid it a visit in 1851, and read a memoir in the winter of that year before the Royal Physical Society of Edinburgh, in which he endeavoured to show that the conglomerate of Cape Wrath was the base, and the quartzites and limestones of Duirness and Erriboll were the middle and upper beds of the Devonian system, corresponding to the same arrangement of the Old Red Sandstone rocks of Caithness. But still no fossils were discovered until, in the end of 1854, Mr. Peach, of Wick, happening to be in Duirness, observed a weathered fossil in a dyke on the road-side; this was enough for his penetrating eye; he immediately set to work; and the result has been, as you all know, the discovery of a complete fauna of Lower Silurian fossils in the Duirness limestone. You are also aware that, with his accustomed energy, Sir Roderick Murchison lost no time in revisiting Sutherland, the scene of his former labours, in company with Professor Nicol, of Aberdeen; that Professor Nicol laid before the Society a memoir containing his opinion that the rocks in question would most likely prove to be the representatives of the Carboniferous system of the south of Scotland; and you are also aware that Sir Roderick Murchison has laid before this Society and the British Association for the Advancement of Science several memoirs containing his present opinions on the relations of the rocks in this district;—that the gneiss of Cape Wrath is the oldest rock in Scotland; that the purple sandstones of Cape Wrath are the next in the ascending order and represent the Cambrian rocks; and, proceeding eastward, that they are succeeded in the ascending order by the quartz-rocks with their associated limestones of Duirness and Erriboll, containing undoubted Lower Silurian fossils in the Duirness beds, and therefore proving that the quartzites and limestones represent the Lower Silurian formation; and lastly, that the great central deposit of gneiss, extending in this locality from the eastern side of Loch Erriboll to the Bay of Strathy, would be found to dip under, or be overlaid by, the Devonian or Old Red Sandstone of the north-east coast of Scotland along the line of junction between the gneiss and the Devonian rocks from Strathy Bay southwards.

Even after the discoveries of Mr. Peach, and since Sir Roderick Murchison published the opinions above stated, I still clung to the hypothesis that, although Silurian rocks undoubtedly existed in the north-west corner of Sutherland, sandstones and conglomerates of true Devonian age would also be found in the same locality, and, to satisfy myself on this point, I revisited the district in question in August last, and the result of my researches and observations has been to convince me that Sir Roderick Murchison is not only quite correct in his facts and deductions, but even in his prospective remarks regarding the progress of future discovery in this region, and that his last memoirs on the subject are only an additional proof of his astonishing sagacity in predicating from premises so slender such clear and comprehensive, and, as the result has proved, such correct views on the geology of so wide a range of country. In giving my adhesion to the views of Sir Roderick Murchison in preference to those of Professor Nicol regarding the age and the true geological position of the various rocks of this district, I beg leave distinctly to state that I found the facts and observations of Professor Nicol regarding the mineralogy and arrangement *in situ* of the various rocks so accurate and complete as to leave nothing further to be desired in that respect. I beg leave further to say, that I believe, had Hugh Miller lived to see the fauna of Silurian fossils discovered by Mr. Peach in the Duirness limestones, he would have changed his views in accordance with the additional evidence thus given upon the points in dispute. I have merely to add that I went over the ground twice in order to verify my observations, and that I shall commence my short descriptions of the various formations with the gneiss of Cape Wrath, and proceed eastward in the ascending order until we arrive at Duncansby Head, on the north-east corner of Scotland.

*Gneiss of Cape Wrath.*—Cape Wrath proper, forming the north-west angle of Scotland, and on which the lighthouse stands, is composed of gneiss intersected by veins of granite; it dips to the south-east at a high angle, and immediately east of, and beside the lighthouse, the dip is almost vertical, with the edges of the upturned strata exposed towards the north in the face of the perpendicular cliffs to the height of 400 feet. Close beside the road, about a quarter of a mile from the lighthouse, there is a small patch of conglomerate resting unconformably upon the edges of the gneiss. The gneiss continues eastward along the sea-shore to Clashcarnoch Bay*. This little bay, about a hundred yards in width, seems to have been formed by the continued action of the waves along the line of a fault in the face of the perpendicular cliff, and forms the very picture of sterility and desolation; it is the only landing-place in the vicinity, and the Lighthouse Commissioners have erected a boat-slip there for landing stores for the lighthouse. The dip of the gneiss is here almost vertical, inclining however to the south-east. From Clashcarnoch Bay it is then prolonged on the sea-shore to Kerwick Bay, about three miles from Cape Wrath, at an altitude of from 300 to 400 feet above the level of the sea; and at the west side of Kerwick Bay it suddenly sinks into the sand, and is succeeded by the sandstone of Cape Wrath as it is generally termed.

*Sandstone of Cape Wrath.*—On the east side of Kerwick Bay the purple sandstones and conglomerates rise into a perpendicular cliff to the height of from 400 to 500 feet above the level of the sea. Immediately at the foot of this cliff seaward is the detached and picturesque rock of "Stack o Chlo," with its horizontal lines of stratification corresponding exactly with those of the adjoining mainland. From Kerwick Bay the sandstone extends eastward for four or five miles along the sea-shore, and it is well seen along the road for the same distance. It extends southward for twelve miles to the rivulet of Achriesgill, within two miles of Rhiconich Inn, and within

* At Clashcarnoch Bay the massive solidity and mineralogical peculiarities of the gneiss of Cape Wrath can be seen to great advantage.

those limits it rises into several lofty elevations of 1000, 1200, and even 1500 feet above the level of the sea. Along the eastern side of the deposit, so far as I have been able to observe, it dips gently to the east or south-east. From the sea on the north to the neighbourhood of the Ferry-house, on the west side of the Kyle of Duirness, it is overlaid by the quartzite. This junction of the two formations, as alluded to by Professor Nicol, can be clearly seen on the road-side within half a mile of Dall, and is very distinct. From the Ferry-house southwards the gneiss juts out until the quartzite reappears as the superior rock beside the road on the north-eastern flank of Ben Farvel. From this point southwards to the rivulet of Achriesgill the junction of the sandstone with the gneiss and quartzite of Ben Spinnue and Finaven is covered over by moss and heather; but it is evidently overlaid by the latter of those two mountain-ranges on the east, as, wherever the sandstone is visible south of Gualin House, it dips to the east at an angle which runs directly under the base of Finaven, particularly on the east side of Loch Taravie. But the most convincing proof that the purple sandstones of Cape Wrath dip under and are older than the quartzites and the great central gneiss deposit of the Highlands, and must therefore be regarded as Cambrian and not Devonian, is to be obtained from the various sections in the bed of the rivulet of Achriesgill within a hundred yards of the road, where the sandstone is distinctly seen dipping to the east and passing into and under the gneiss of Craigmore, which, notwithstanding its confused and rugged aspect, can also be seen dipping to the east.

*Quartzite.*—As I have stated in the foregoing section, the quartzite succeeds and overlies the Cape Wrath sandstone, and on the west side of the Kyle of Duirness it passes into gneiss so frequently that it is difficult to define its limits. Between Dall and the Ferry-house it dips to the east. On the east side of the Kyle of Duirness it reappears at Lerinmore Bay; its junction at this point with the limestone is covered over by earth and debris and cannot be well seen; it continues along the shore eastward to the gneiss of Ben Keannaben; it is seen in Klourig Island at the mouth of Loch Erriboll, appears on the western shore of Loch Erriboll about four miles from Rispond, extends from this point southwards until it meets the gneiss of Craig na fielin at the south end of Loch Erriboll, reappears at the mouth of the River of Hope, on the east side of Loch Erriboll, runs northwards to Whiten Head, and into and under the gneiss on the eastern side of that noble promontory.

*Limestone.*—The limestone is first seen in Garve Island and in the mainland nearly opposite, on the north-west side of the Kyle of Duirness; but as it is here of minor importance, I did not pay it a visit. The principal portion of the deposit is on the east side of the Kyle, and extends southwards from a point north-east of Balnakiel House to the Bridge of Grudy, and westwards from the River of Grudy for about a mile round the Head of the Kyle; its extreme length may be seven miles and its breadth about three miles in its widest part, extending from the shores of the Kyle to the mountain-range of Meal Meannach. This extraordinary ridge of vertical gneiss rises out of the sea at Ben Keannaben near Rispond in a perpendicular cliff 200 or 300 feet high, runs south-west for about seven miles, attaining an elevation of 2500 feet in Ben Spinnue, and it is against this immense wall of rock of vertical gneiss that the whole eastern side of the Durness limestone rests.

The greater part of the western front of the limestone extending along the shore of the Kyle exhibits as beautiful an example of the elevation of the land at different and very distinct periods as I have ever seen; several raised terraces or old sea-beaches with rocky fronts can be distinctly traced along the whole western line. But it is at the point opposite the old Ferry-house that the finest succession of terraces is seen; here six different terraces can be counted, each terrace extending half a mile in length, and presenting a rocky front of about 15 feet in height, the highest and farthest removed from the sea being a quarter of a mile from the present coast-line and about 100 feet above the level of the sea. These terraces, like the rock itself, all dip to the south-east.

It is not my present intention to allude to the fossils of this deposit further than to say that Mr. Peach has discovered them in various parts of the Duirness limestone, both on the sea-shore and in the interior, that Mr. Salter has pronounced them to be Lower Silurian, and that his decision has been approved of by other palæontologists. There is one feature, however, of the Duirness limestone to which I would advert, and which made it to be generally known and an object of interest even before the discovery of the fossils, and that is the celebrated Cave of Smoo.

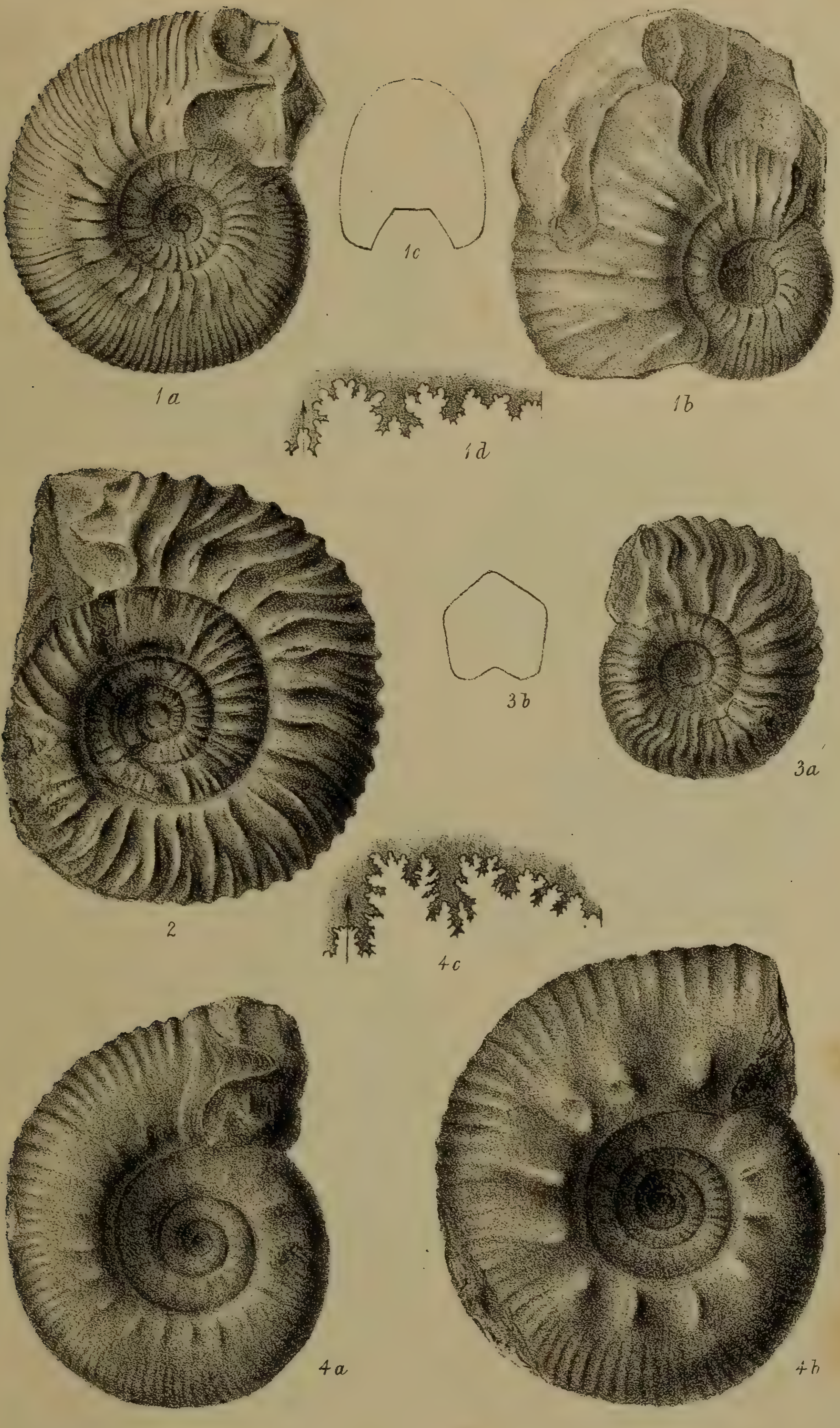
The cave itself has been so often described and is so well known to tourists that any further description is unnecessary. It is the creek or cove at the upper end of which is the cave proper which is interesting to the geologist, because it exhibits the finest sections of the limestone which are to be found in the whole deposit. This creek runs into the land nearly due south for about 400 yards, the width varying from 30 to 40 yards, and the sides ranging in perpendicular cliffs from 30 to 80 feet in height. The black and gloomy aspect of the cliffs is relieved by regular horizontal layers of white quartz 6 inches in thickness, intercalated or stratified along with the limestone at distances of from 6 to 8 feet apart, giving the cliffs the appearance of the side walls of a noble cathedral of Nature's own building. Throughout the whole deposit, wherever you get a good section of a cliff, these layers of quartz appear always conformable to the limestone and dipping with it at the same angle. The layers are sometimes only 2 feet apart, giving the appearance of regular tiers of masonry to a large portion of the deposit. The thickest of these interstratified layers of quartz is within a few yards of the road at the ground-officer's house, Sandgoe Bay; it is from 3 to 5 feet in thickness, very compact, and of a milky whiteness, and may some day prove valuable for economic purposes. Still proceeding eastward the limestone reappears in Island Hoan, at the mouth of Loch Erriboll, and in Island Chonie, near the south or upper end of the loch. On the mainland it is visible at the head of the loch in the face of the magnificent cliff called Craig na fielin, some 600 feet high, in the shape of a narrow belt about 3 feet wide extending in a straight line from the bottom about two-thirds of the whole height upwards, dipping to the east conformably with the enveloping body of gneiss. In this section we have a well-marked example of a true limestone apparently altered by heat, regularly interstratified with gneiss above as well as below; and to remove all doubt in the matter, large masses of the limestone, loosened by the frost and rains, have fallen down and can be seen beside the road, presenting the dull ashen appearance of burnt shale just taken out of a furnace. From Craig na fielin the limestone is continued along the eastern shore of Loch Erriboll nearly to the mouth of the River of Hope, dipping to the east and overlaid by the gneiss and quartzites. In one of his memoirs Professor Nicol says it can be traced northwards from the River of Hope to Whiten Head; and to satisfy myself on this point, I went by boat to Whiten Head and coasted along the cliffs to the River of Hope, but failed to detect the limestone north of the River of Hope. I do not assert, however, that there is no limestone to be seen in that locality, because the cliffs are high, attaining the elevation of 500 feet at Whiten Head, and during spring tides (which was the case when I visited it) it is dangerous to approach too near the cliffs, and I merely leave it to future observers to describe the limestone of Whiten Head.

*Central Gneiss of the North Highlands.*—In one of his late memoirs on this subject, Sir Roderick Murchison says that "this deposit, from its junction with the sandstones and quartzites of the west coast, rolls over the central districts of the North Highlands until it meets the Devonian rocks of the east coast;" and the description is a most happy one. From the eastern shores of Loch Erriboll eastward to the River of Strathy, and even to the centre of Caithness at Dirlet Castle, the gneiss generally dips to the east or south-east, and literally rolls over this wide extent of country (nearly 70 miles) unchecked by any other formation; and it can be seen passing under and beyond the sandstones and conglomerates in the neighbourhood of Tongue, at Rhi Tongue and Coldbackie, and other places, and continuing its course eastward in one unbroken formation, at least on the north coast, until it reaches the points just mentioned. I do not mean that throughout this distance it always dips to the east, because it often exhibits very fine examples of vertical strata, as in the hill which the road ascends immediately after crossing the River of Borgie going eastward, and again at the parish church of Farr; and wherever a hill of elevation occurs, there a western dip is generally visible as well as an eastern dip; but, as a quarryman of the district told me when I was examining the rocks, "All the quarries in Lord Reay's country work to the eastward," which was tantamount to a declaration that all the rocks in the northern half of Sutherland dip to the east,—as the quarrymen in this country follow the dip, their quarries being generally worked not far from the surface; and when we see the gneiss dipping to the east and overlaid by the true Old Red Sandstone or Devonian rocks, as proved by its fossils, at Portskerray, Sandside, various places in the parish of Reay, Dirlet Castle, in the neighbourhood of the Ord of Caithness, and of the Morven range of hills, we must admit that Sir Roderick Murchison has proved the correctness of his hypothesis, and at length established the geology of the north of Scotland on a sound basis.

*Old Red Sandstone or Devonian Rocks of the North Coast of Scotland.*—I have just shown in the preceding section that they overlie and follow in true geological sequence the central deposit of gneiss, and, as their upper beds are to be found in the red sandstones of Dunnet Head and of Duncansby Head, overlooking the German Ocean, they must therefore be regarded as at the top of the geological scale on the north coast of Scotland. I look upon the sandstones and conglomerates in the neighbourhood of Tongue as belonging to this system, and I doubt not that future explorations may bring to light additional patches of sandstone on the hills near the north coast of Sutherland, which may connect the Tongue sandstones with those of Strathy and Portskerray. It has long been an interesting question amongst geologists, at what period did the denudation of the sandstones and conglomerates of the North Highlands take place?—was it at the glacial period, when the boulder-clays of Caithness and the north-east of Scotland were deposited? A careful examination and mapping-out of the remains of the sandstones and conglomerates on the hills of Sutherland and Ross might do much to settle the question and should be kept in mind by our younger geologists.

Instead of giving a detailed description of the Devonian rocks of this district, I must in strict justice rather refer to the admirable memoir of Messrs. Sedgwick and Murchison on this subject laid before the Society thirty years ago, for nothing can surpass the faithfulness and beauty of their descriptions or the comprehensive and satisfactory manner in which they draw their conclusions; in fine, it is so copious and correct, that, with the addition of a few notes explanatory of the discoveries of Professor Traill and Hugh Miller, Mr. Dick of Thurso, and Messrs. Cleghorn and Peach, of Wick, regarding the boulder-clay and the organic remains of the formation generally, it would serve as an excellent and most able report on the geology of Caithness, so far as known at the present day.

*Concluding Remarks.*—In the foregoing short descriptions of the various formations, I have pointed out the order of superposition of each formation as we came along in our narration from the west to the east coast, and I think it has been distinctly proved that the gneiss of Cape Wrath lies at the foundation of the system, followed by the sandstone of Cape Wrath, quartzites and limestones of Duirness and of Loch Erriboll, central gneiss of the North Highlands, and Devonian rocks extending from Strathy to Duncansby Head, at the top of the system, on the German Ocean; and while we are glad that the leading points of the geology of this interesting region have at length been satisfactorily ascertained, we should remember that much still remains to be done in its palæontology,—the Duirness limestone and the fossiliferous beds of Caithness are not half explored, and laurels are still to be gained by successful labourers in those localities.

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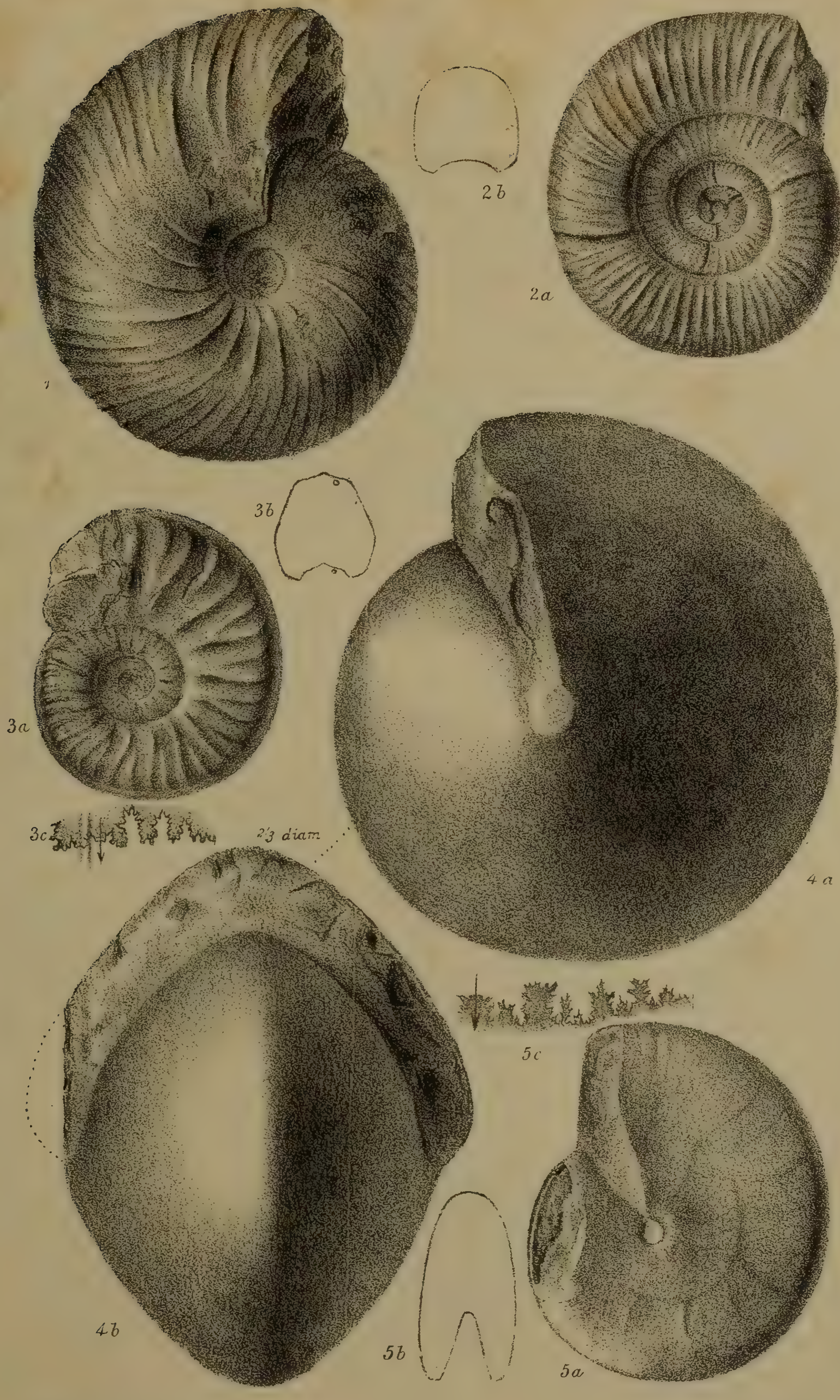
KELLOWAY ROCK, YORKSHIRE.

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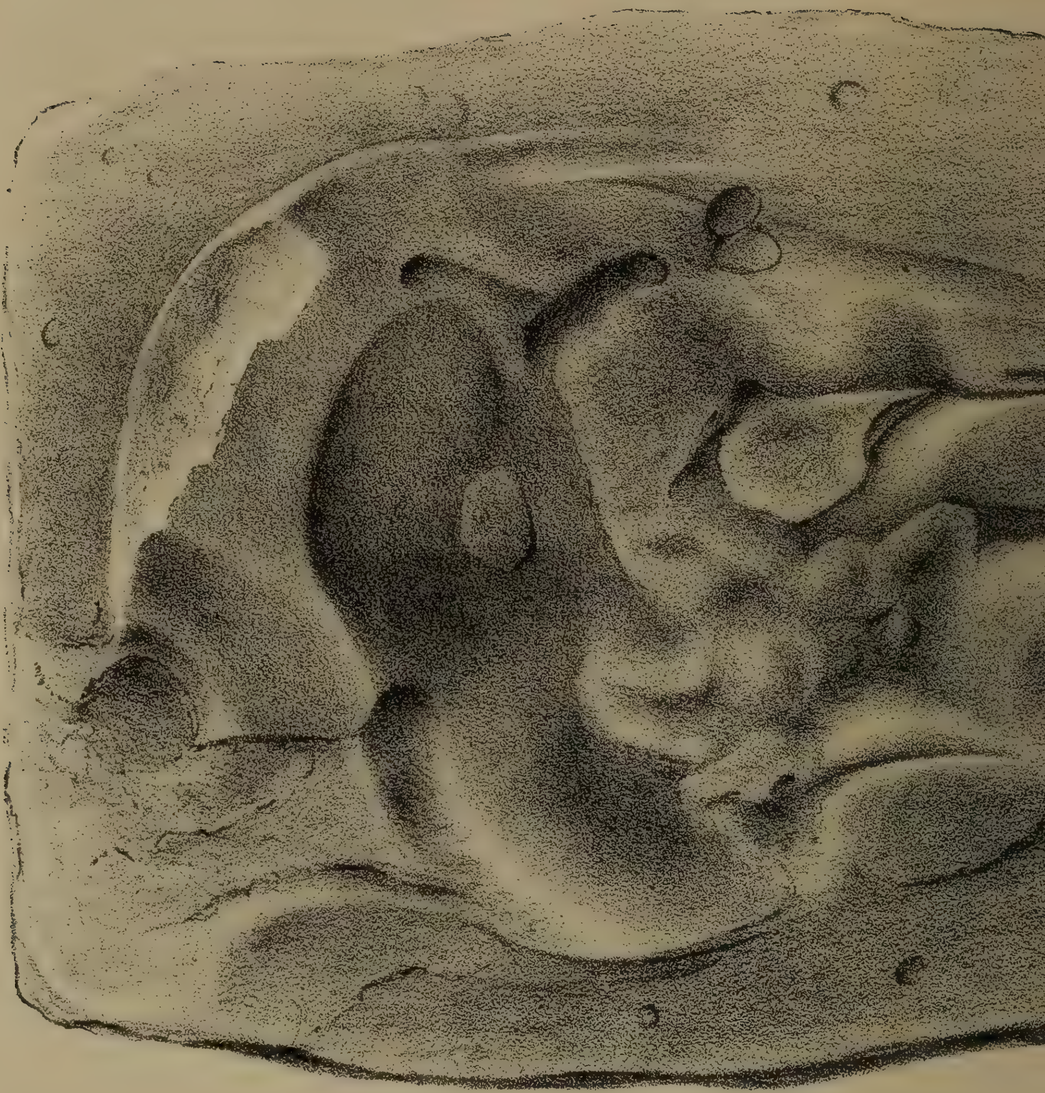

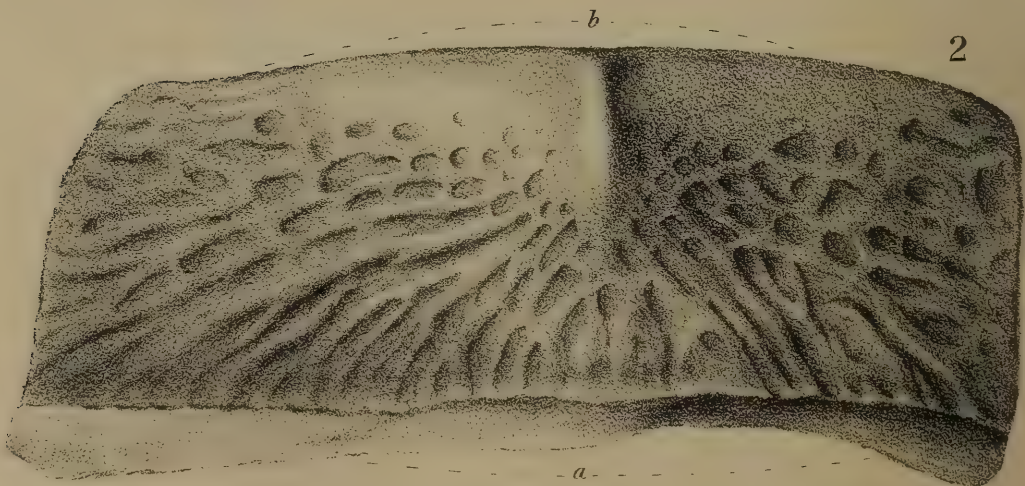


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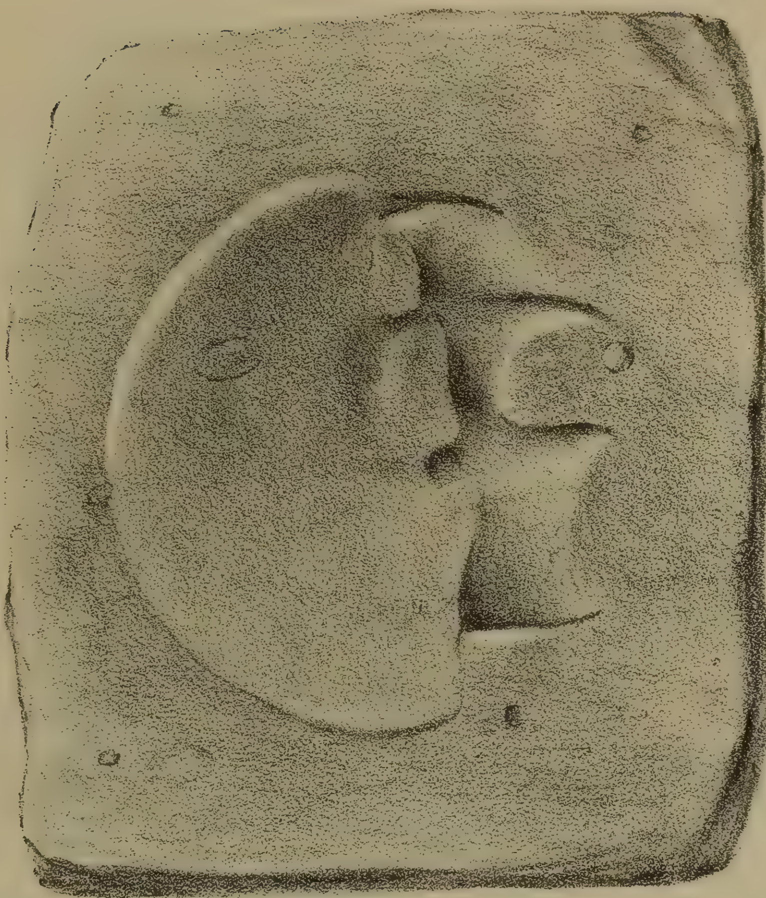

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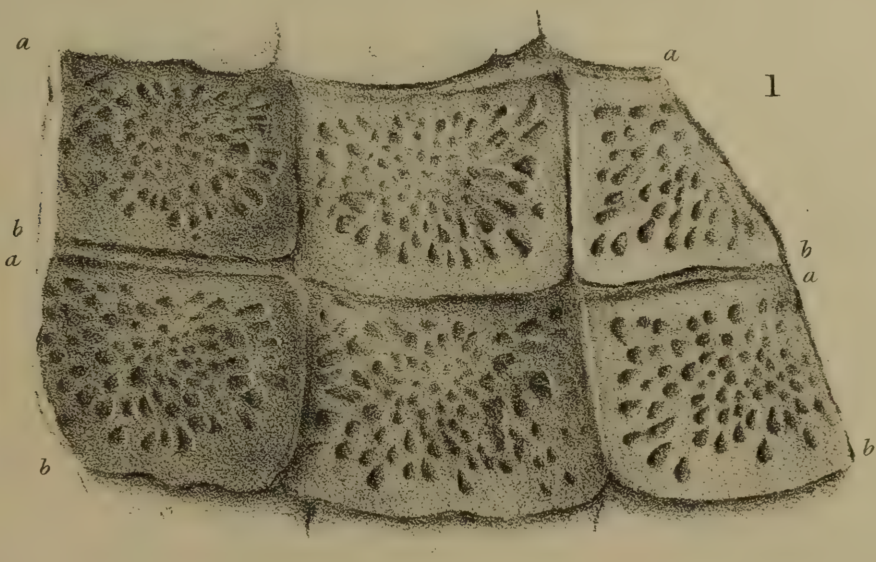


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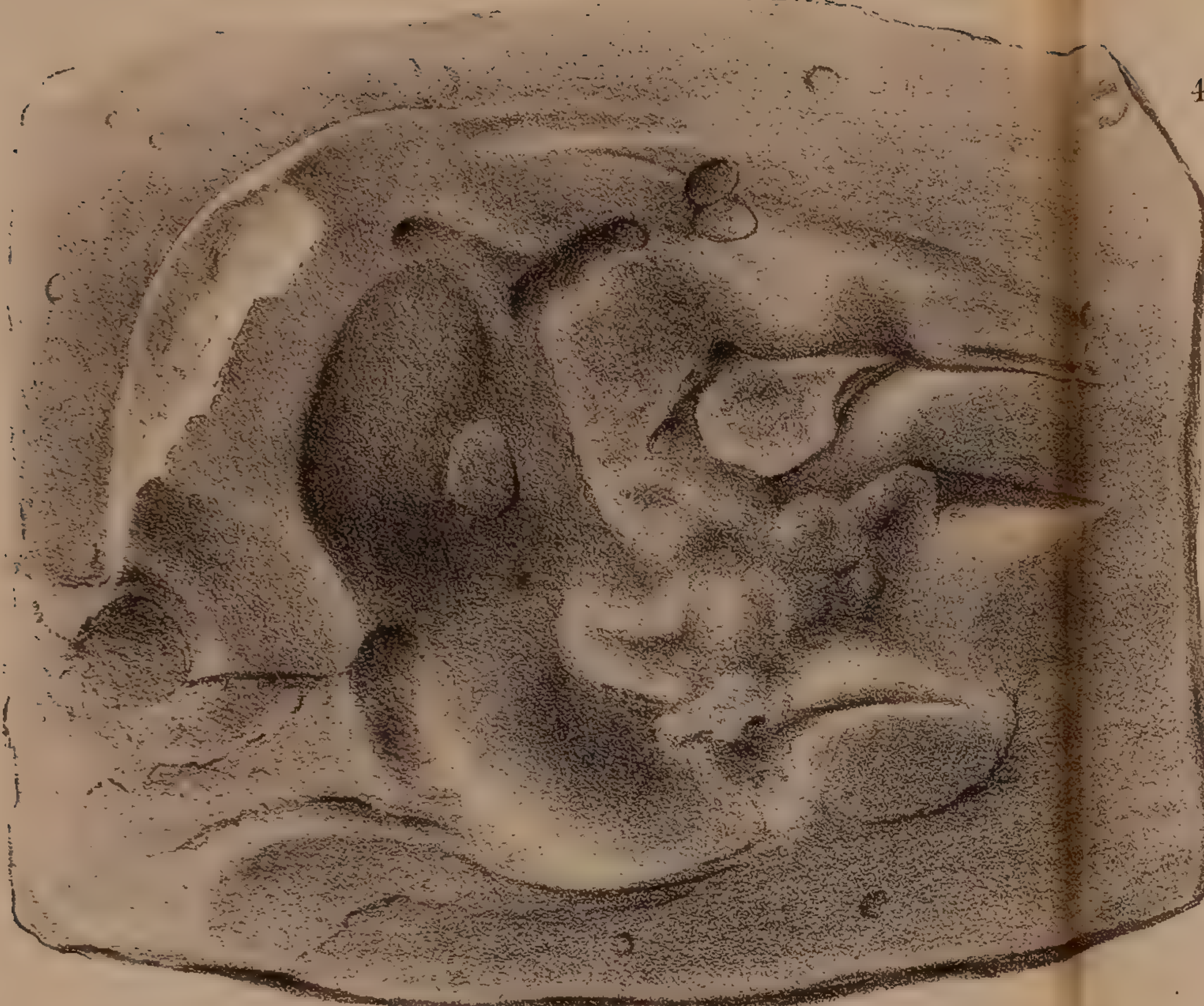

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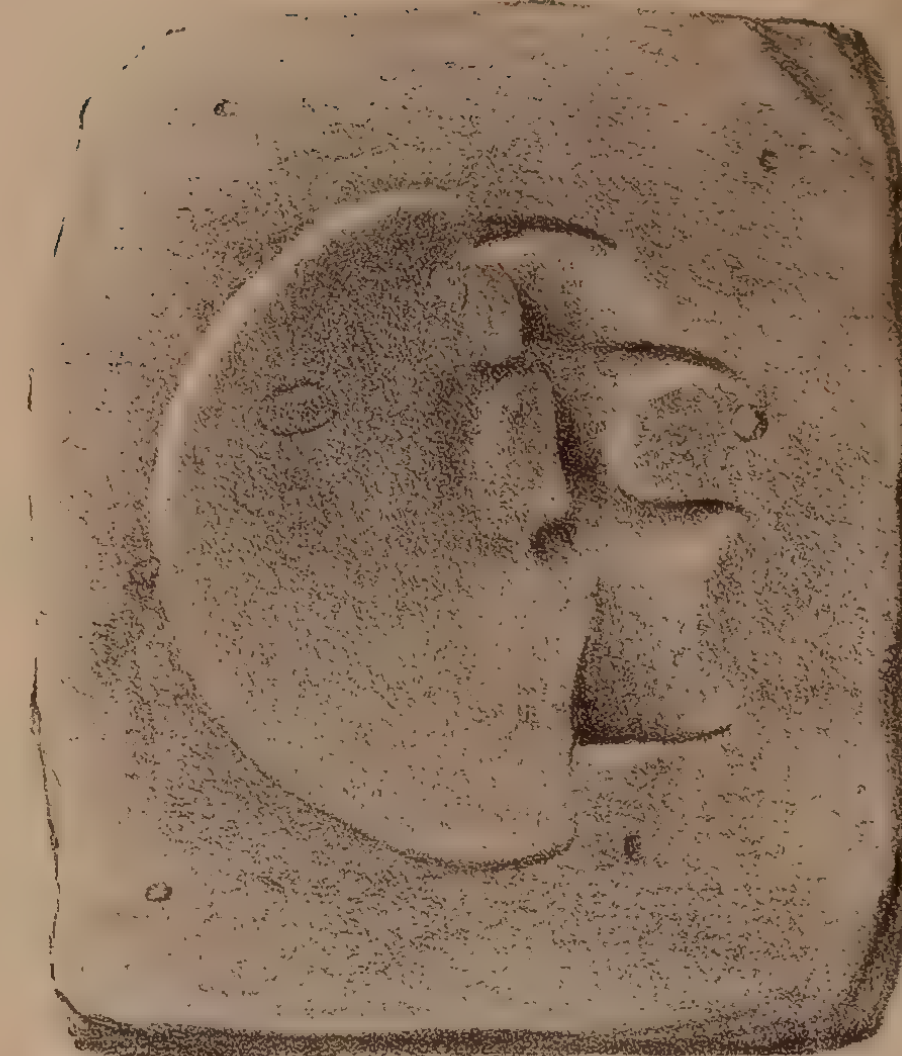

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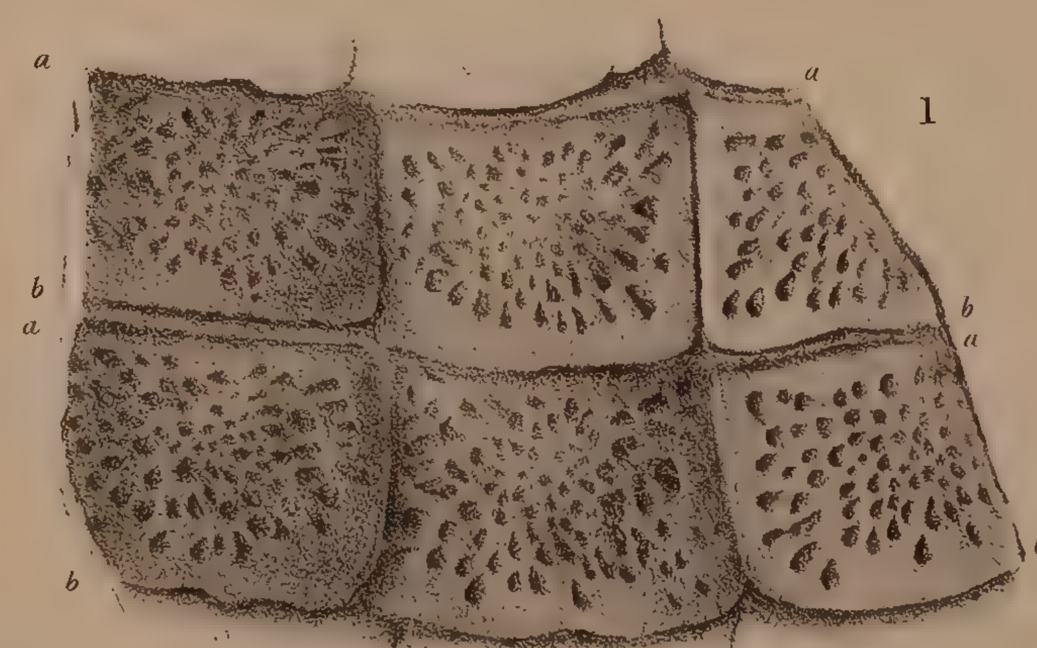


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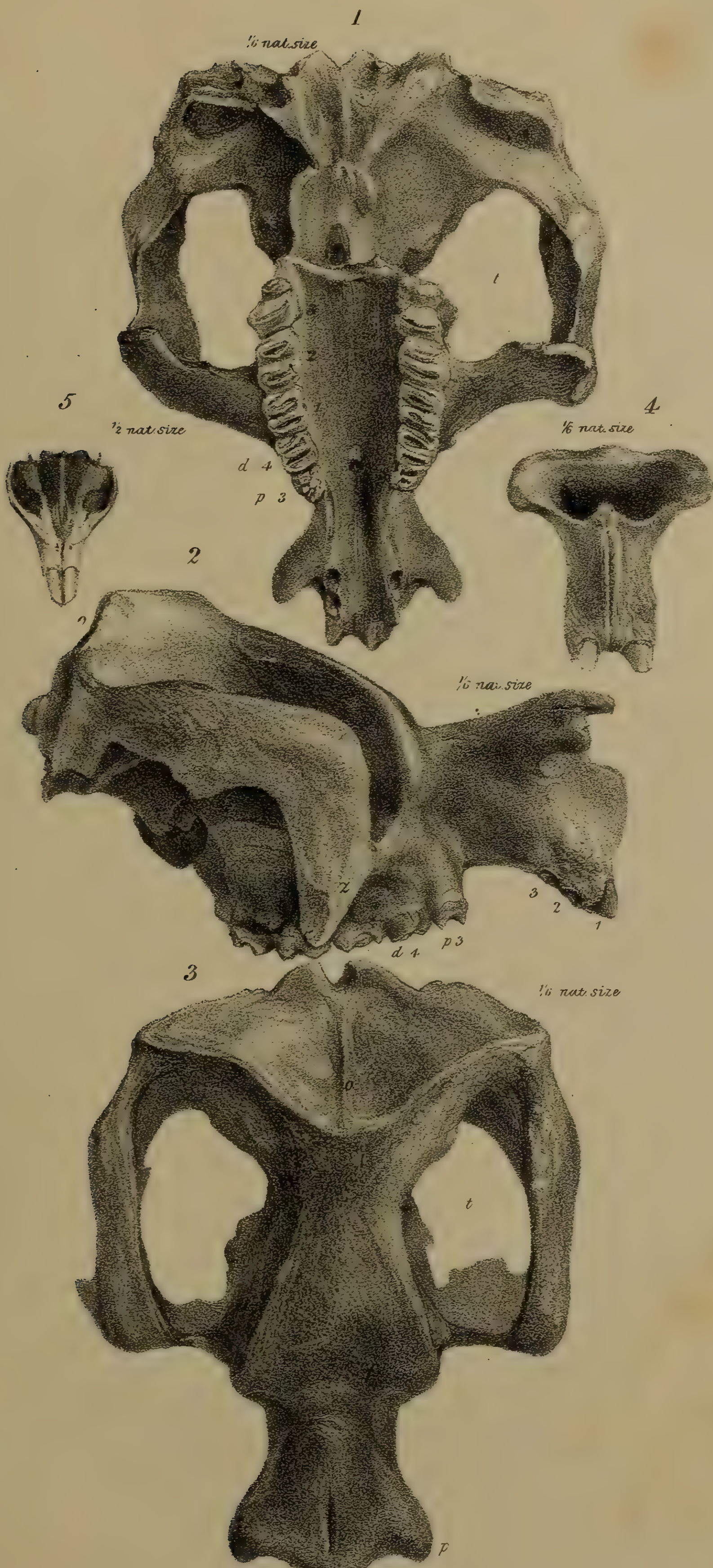
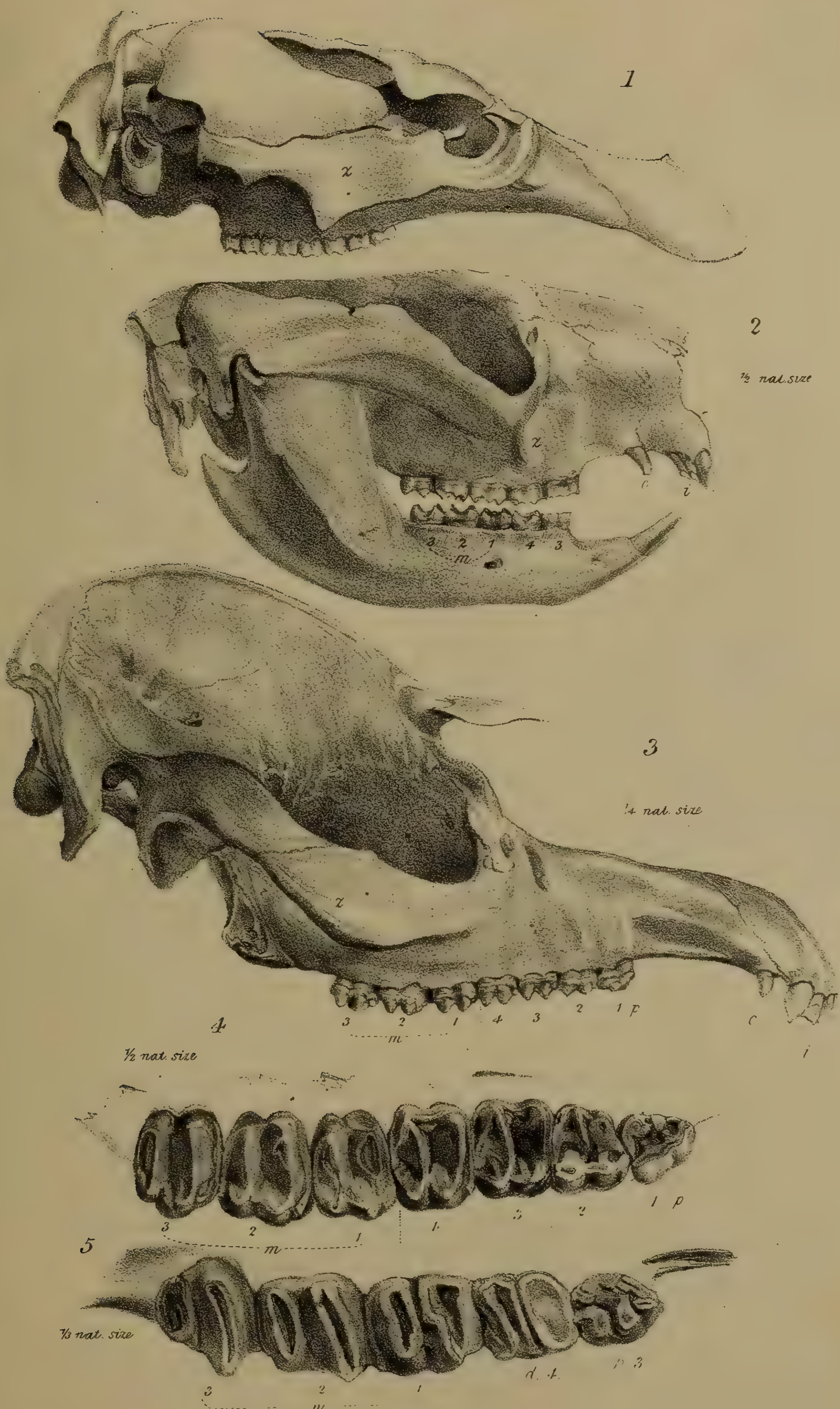
STAGONOLEPIS




Nototherium &c.

From Nature on Stone by J. Erxleben. Day & Son, Lith^rs to the Queen.




Manatus, Phascolarctus, Tapirus, & Nototherium.

m Nature on Stone by J. Erxleben.

Day & Son, Lith^rs to the Queen.


Nototherium & Diprotodon.

m Nature on Stone by J. Erxleben

Day & Son, Lith^rs to the Queen

# TRANSLATIONS AND NOTICES

OF

# GEOLOGICAL MEMOIRS.

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*Investigations of the* Laws *of* Development *of the* Organic World *during the period of the* Formation *of the* Earth's Surface. By Dr. H. G. Bronn. Stuttgart, 1858.

[Untersuchungen über die Entwickelungs-Gesetze der organischen Welt während der Bildungs-Zeit unserer Erd-Oberfläche. Eine von der Französischen Akademie im Jahre 1857 gekrönte Preisschrift. Von Dr. H. G. Bronn. Stuttgart, 1858.]

This remarkable work by Prof. Bronn, of Heidelberg, is the German translation of the essay to which the prize was awarded by the French Academy in 1856. The original subject proposed in 1850 and 1854 was,—1st, "to examine the laws of the distribution of fossil organic bodies in the different sedimentary formations according to the order of their superposition; 2nd, to discuss the question of their successive or simultaneous appearance or disappearance; 3rd, to inquire into the nature of the relations between the existing state of the organic world and its anterior states."

The work consists of two parts: the first contains the introductory remarks and tabular statements of the materials on which the author's views are grounded, and which are chiefly taken from D'Orbigny's works and the 'Lethæa;' viz. the different geological formations, the distribution of organic life, numerical proportions of fossil species and genera, of fossil genera now living and those which are extinct, the geological extension of the different classes of organic life.

Having thus carefully collected his materials, the author proceeds in the second part to deduce the laws which have regulated the phænomena of organic life in different geological periods, and the appearance and disappearance of different forms. This part consists of three subdivisions:—1st. Theoretical development of the laws of the succession of organic beings. 2nd. Practical tests of the theoretically developed laws by the examination of the organic remains in the successive geological strata; and 3rd, the results of these inquiries.

A few extracts from different portions of the work will show the reader how the author has executed this great problem. The second part commences with these words:—"The crust of the earth is a big book; its strata are the leaves, its fossils are the letters of the alphabet with which it is written, and its contents are the history of the Creation, of which no living witness can give us information. But the leaves lie before us imperfect, torn, scattered, and partially obliterated; we must arrange them and endeavour to supply what is missing; many gaps can be restored from other parts; the interpretation is often vague, and the discovery of new fragments hitherto wanting often renders it necessary to correct earlier arrangements" (p. 75.)

The author then proceeds (p. 77) to describe the Creative force in the following manner:—

"We have stated that the great book of the history of the earth describes all the events which took place during its formation, and points out to us the succession of the forms of the organic kingdoms. But it leaves us entirely in the dark respecting the force which produced the latter. We perceive that the same physical and chemical natural forces which now guide and regulate all the movements and changes in the inorganic world have also sufficed to originate and to continue those which have formed the earth and its crust; but in the present day we see no new genera or species arise; the power which produced them is unknown to us, and even the earth's strata do not afford us the means of deciphering it. The humble naturalist who knows of no natural force which could form species of plants and animals as attraction formed the spherical heavenly bodies, and as affinity formed the crystallized varieties of minerals, is disposed to consider them as the immediate emanation of a divine creative act. But this same humble naturalist must also say to himself that nothing else in nature acts by such a power, but that everything is arranged and formed by universal laws implanted in the matter itself; that here also analogy necessarily leads us to presuppose a similar, although to us unknown, power, which has produced the species of plants and animals, and which perhaps, as has been assumed by Lyell, still continues, although only on rare occasions, to produce them."

The author then alludes to the doctrine of *generatio equivoca* or *spontanea* adopted by some authors, and the Lamarckian theory of gradual transformation and adaptation, by which it was attempted to get over some of these difficulties, and shows how they have been disproved, observing that "no experience proves that any one species or genus, or even an order or a class, has really been transformed into another. And as for those palæontologists who maintain that only the first plants and animals of the earth were produced by immediate creation, they have obtained no real simplification of the laws of nature by merely limiting the period of immediate creation to a somewhat shorter time.

"We have, however, already stated that the naturalist would be inconsistent were he to derive the organic world alone from an immediate creation, whilst everything else comes and goes, arises and disappears, by means of universally distributed, and eternal natural forces, as occurs in the case of the propagation of a once existing species of animal or plant by sexual descent, or by sprouting and budding; and that he would be equally inconsistent if he trusted to a *generatio spontanea*, which has never been proved. And yet we know of no third explanation.

"We will therefore at least attempt to describe that organization-creating power more closely by means of its operations, while we postpone the proofs that these operations really took place to a subsequent portion of this essay.

"1. The first productions of this power in the oldest Neptunian strata of the earth consisted of Plants, Zoophytes, Molluscs, Crustaceans, and perhaps even Fish; the simultaneous appearance of which, therefore, contradicts the assumption that the more perfect organic forms arose out of the gradual transformation in time of the more imperfect forms.

"2. The same power which produced the first organic forms has continued to operate in intensively as well as extensively increasing activity during the whole subsequent geological period, up to the final appearance of man: but here also can no traces be found of a gradual transformation of old species and genera into new; but the new have everywhere appeared as new without the cooperation of the former.

"3. In the succession of the different forms of plants and animals, a certain regular course and plan is perceptible, which is quite independent of chance. Whilst all species possess only a limited duration, and must sooner or later disappear, they make way for subsequent new ones, which not only almost always offer an equivalent, in number, organization, and duties to be performed, for those which have disappeared, but which are also generally more varied, and therefore partly more perfect, and always maintain an equilibrium with each other in their stage of organization, their mode of life, and functions. There always exists, therefore, a certain fixed relation between the newly arising and the disappearing forms of organic life.

"4. A similar relation necessarily exists between the newly arising organic forms and the outward conditions of life which prevailed at their first appearance on the earth's surface, or at the place of their appearance.

"5. A fixed plan appears to be the basis of the whole series of development of organic forms, in so far as man makes his first appearance at its close, when he finds everything prepared that is necessary to his own existence and to his progressive development and improvement,—which would not have been possible had he appeared at a former period.

"6. Such a regular progress in carrying out the same plan from the beginning to the end of a period of millions of years can only be accounted for in one of two ways. Either this course of successive development during millions of years has been the regular immediate result of the systematic action of a conscious Creator, who on every occasion settled and carried out not only the order of appearance, formation, organization, and terrestrial object of each of the countless numbers of species of plants and animals, but also the number of the first individuals, the place of their settlement in every instance, although it was in his power to create everything at once,

—or there existed some natural power hitherto entirely unknown to us, which by means of its own laws formed the species of plants and animals, and arranged and regulated all those countless individual conditions; which power, however, must in this case have stood in the most immediate connexion with, and in perfect subordination to, those powers which caused the gradually progressing perfection of the crust of the earth, and the gradual development of the outward conditions of life for the constantly increasing numbers and higher classes of organic forms in consequence of this perfection. Only in this way can we explain how the development of the organic world could have regularly kept pace with that of the inorganic. Such a power, although we know it not, would not only be in perfect accordance with all the other functions of nature, but the Creator, who regulated the development of organic nature by means of such a force so implanted in it, as he guides that of the inorganic world by the mere cooperation of attraction and affinity, must appear to us more exalted and imposing, than if we assumed that he must always be giving the same care to the introduction and change of the vegetable and animal world on the surface of the earth as a gardener daily bestows on each individual plant in the arrangement of his garden.

"7. We therefore believe that all species of plants and animals were originally produced by some natural power unknown to us, and not by transformation from a few original forms, and that that power was in the closest and most necessary connexion with those powers and circumstances which effected the perfection of the earth's surface."

The author then briefly alludes to the various laws of the development of organic beings which have hitherto been brought forward; and then, after pointing out their insufficiency, proceeds to describe the two elementary principles which have regulated the sequence of organic beings in the following manner:—

"If we then commence by laying down a theoretical development of the laws of succession of organic beings, it must be understood that this is not done merely as an abstract question, but in anticipation of the results of the observations and remarks which we have collected during a long period of years; and we thus arrive at a result, to the actual proof of which the greater part of the following essay will be devoted. The sequence of organic beings, from the very first commencement of creation to the appearance of our present vegetable and animal world, has been regulated by these two laws:—

"1. By an independent productive power constantly advancing in an intensive as well as extensive direction [or degree].

"2. By the nature and change of the outward conditions of existence under which the organic beings to be called forth were to live.

"We have already stated that both these laws are in the closest connexion with each other, although we cannot understand the productive power. The first of these laws is positive, the second negative, so far as we can consider them in a separate point of view.

The first is inherent to the producing-creating force, and is so far independent as the force itself is independent. The second depends on outward circumstances, which, however, always advance in a parallel direction with that force, and render possible the existence of more and more perfect beings in the same degree as those are produced by the former. But, whilst on the whole both work progressively, parallelly, and simultaneously, the positive law is in individual cases frequently modified by the negative, inasmuch as those organic beings for which the outward conditions of existence are not suited not only cannot exist, but cannot even be produced or created. The condition of creation must, therefore, accurately coincide or be identical with the condition of maintenance; the creating force must coincide with the maintaining force, although the maintaining conditions are not always necessarily producing conditions."

It would far exceed the limit of this notice to follow the author through the proofs and reasonings by which he endeavours to establish the laws which we have laid before the reader, and which he considers proved by a careful study of every branch of natural history; but we must, in conclusion, state that it is impossible to open a single page in this interesting work without being struck with the deep research which it evinces, or without deriving information from the numerous facts which are so harmoniously brought together in confirmation of his views. The chapter on "Species," p. 227, is in the present state of the discussion of that subject particularly deserving of notice. [W. J. Hamilton.]

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## *A New Contribution to the* Tertiary Flora *of the* Brown-coal *of the* Lower Rhine. By Dr. P. Wesel and Dr. O. Weber.

[Neuer Beitrag zur Tertiär Flora der Niederrheinischen Braunkohlenformation. Von Dr. Phillipp Wesel und Dr. Otto Weber, zu Bonn (with 11 Plates). Cassel, 1856.]

This is an important contribution to our knowledge of the rich Tertiary Flora of the Brown-coal formation on the Lower Rhine. Whatever judgment we may form as to the value and authority of generic and specific determinations of plants from the leaves alone, there can be no doubt as to the great service done to science by the publication of careful descriptions and well-executed figures of these remains, which will afford most valuable materials to all future investigators.

The abundance and variety of vegetable remains in the tertiary formation in question appear to be very remarkable. The greatest part of them are merely detached leaves, but often in an excellent state of preservation, insomuch, in some cases, that the microscopic structure of the epidermis, with its pores, can be satisfactorily examined and compared with that of recent leaves. As many as 111 distinct forms (considered as so many species) are named and described (mostly for the first time) in the present work; but, it appears, from a tabular view given in the introductory part, that, including those described in other works, the number of fossil plants, already known, from the Brown-coal of this one district amounts to 237 supposed species. Of these, 94 have been found in other tertiary localities, especially Œningen, Hæring in the Tyrol, Parschlug in Styria, Radoboj and other localities in Croatia; 143 have as yet been detected nowhere but in the Rhenish district. As regards the geological relations of the localities above mentioned, Œningen is well known to be pliocene, and Parschlug is referred to the same age by M. Adolphe Brongniart*; while Radoboj is considered as of miocene age, and M. Brongniart seems to place in this latter division the very formation† of Brown-coal of which we are here speaking. But the exact geological age of these lignite-deposits seems often difficult to fix.

The number of species above stated must be received with considerable caution; for, in more than one instance, Dr. Weber himself expresses a suspicion that leaves which are described in the present work under two or three different specific names may in fact belong to one and the same plant. Taking the species, however, as they stand in this enumeration, we find that, among the 237, there are 5 Ferns, 3 Palms, 21 Coniferæ, 15 species of Quercus, 13 Laurineæ, 7 Proteaceæ, 9 species of Acer, 7 of Juglans, and 18 Leguminosæ.

There are, moreover (described in the present work), 1 species of *Causarina*, 2 of *Betula*, 1 *Alnus*, 1 *Corylus*, 1 *Fagus*, 6 species of *Carpinus*, 4 of *Ficus*, 1 *Liquidambar* (found in many localities of tertiary age, on the European continent), 4 Poplars (2 admitted to be very doubtful), 1 *Leptomeria*, 2 *Aristolochiœ*, 1 *Plumeria*, 1 *Magnolia*, 1 *Nymphœa*, 3 *Eucalypti*, 1 *Rosa*; and among the genera of *Leguminosœ* which are supposed to be identified, are *Templetonia*, *Dalbergia*, *Hœmatoxylon*, *Gleditschia*, *Cassia*, *Ceratonia*, and *Acacia*; some of these being determined by the help of fruits as well as leaves.

This certainly appears an anomalous assemblage of plants, and difficult to reconcile with what is as yet known of botanical geography. It is rather startling to find such numerous species of *Quercus*—a genus entirely wanting in Australia—associated with such eminently Australian forms as *Casuarina*, *Leptomeria*, *Eucalyptus*, and *Templetonia*; and genera characteristic of temperate climates, like *Betula*, *Corylus*, *Carpinus*, and *Populus*, in company with such tropical forms as *Plumeria*, *Dalbergia*, and *Hœmatoxylon*. Again, of the supposed *Proteaceœ* described and figured in the present work, one is referred to the genus *Protea* itself, the rest being considered to belong to *Banksia*, *Dryandra*, and *Hakea*. Now, in the present creation, *Protea* is entirely confined to the continent of Africa, while the three other genera above mentioned are altogether peculiar to Australia‡.

In fact, as was long ago pointed out by Robert Brown, the genera of *Proteaceœ* are strictly limited in their geographical range, and *Lomatia* appears to be almost the only instance in the order of a genus common to two continents. Hence we are disposed to scru-

* Tableau des Genres, p. 119. † Ibid, p. 117.

‡ Including Tasmania.

tinize very closely the evidence on which we are expected to believe that species of *Protea* and of *Banksia* formerly flourished in one and the same district.

Moreover, these supposed *Proteaceæ* are found associated in this tertiary deposit with a remarkable abundance of *Cupuliferæ*; whereas, in the present state of the earth, the countries which chiefly abound with *Proteaceæ* (South Africa and the continent of Australia) are entirely destitute of *Cupuliferæ*.

Still, we must not push this argument too far, nor too hastily and positively reject the evidence for the co-existence, in a former state of things, of groups of plants which our present knowledge leads us to regard as belonging to distinct and separate regions. Our knowledge of botanical geography is still too incomplete to authorize us to say positively that such and such genera or families of plants *cannot* occur in company. Recent discoveries have given several cautions against too absolute a dogmatism on such points. Not very long ago, it would have been thought most improbable that numerous species of *Rhododendron* should be found in the Island of Borneo, almost under the equator. Yet such is ascertained to be the fact; and on the same mountain with these Rhododendrons, and with species of *Nepenthes* and other especially tropical genera, has been found a new species* of a very peculiar genus of *Coniferæ* (*Phyllocladus*), otherwise confined to Tasmania and New Zealand; and another plant belonging to a genus (*Drimys*) of which the previously known species were shared between South America and New Zealand. The fact pointed out by Dr. Hooker†, of a species of Rose growing wild abundantly in the tropical plains of Bengal, is another striking *exceptional* instance. The vegetation of the Khasia Mountains, so well described by the same great botanist, seems to present some analogy to the curious mixture of forms characteristic of the Brown-coal flora; in particular, one or more well characterized *Proteaceæ* (*Helicia*) grow there in company with numerous Oaks. We must remember, too, it is possible that the plants of the Rhenish Brown-coal may not all have grown at the same elevation; some may have been brought down by rivers or floods from higher districts.

On the whole, we may probably conclude, with some confidence, that this Brown-coal flora indicates a climate considerably warmer than that now prevailing in Middle Europe, yet not absolutely tropical.

The number of species of Ferns in this list (five) is small in proportion to the total number of plants, being not quite 1 : 47. A small proportional number of Ferns seems characteristic of most of the tertiary floras hitherto described; probably there was something in the nature of the localities where these deposits were formed, unfavourable to this family of plants.

Mosses are so rare in a fossil state, that the occurrence of a single well-marked Moss in the deposit in question is interesting.

* 'Himalayan Journals', vol. ii.

† See Sir W. Hooker's 'Icones Plantarum', vol. ix.

Wesel and Weber have named it *Hypnum lycopodioides*; forgetting, seemingly, that this name had been long since appropriated to a recent species, quite different. [C. J. F. Bunbury.]

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*On the* Tertiary Beds *of* Sotzka, Styria. By Dr. Rolle.

[Proceed. Imper. Acad. Vienna. April 22, 1858.]

Abundant as is the fossil flora preserved in the lignite-beds of this locality, the discovery of animal remains was wanting for the precise determination of their geological age. Dr. Rolle has now found in them a number of marine and fresh-water species, which, with one exception, not being known to occur in other localities, prove the Sotzka Tertiaries to be of more ancient date than those of the Vienna Basin. The opinion (first promulgated by L. v. Buch and since held by Prof. Heer) of the Sotzka strata being coeval with those of Eibiswald, Johnsdorf, Parschlug, &c., must therefore give way to that published by Prof. Unger in his first descriptions of the Sotzka Flora; and these Tertiaries are to be parallelized with the middle, or at least with the uppermost, strata of the Sotzka Basin.

[Count M.]

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*On the* Danubian Tertiaries.

By MM. Sandberger and Gumbel.

[Proceed. Imper. Acad. Vienna, June 10, 1858.]

A belt of Tertiary deposits, of variable breadth, runs along the northern slope of the Alps from Marseilles to Vienna, forming the so-called "Upper Danubian Basin," the greatest breadth of which lies at and around Munich. The real age of these Tertiaries, in comparison with the Molasse of Switzerland, and with the Mayence and Vienna Basins, has long remained an unsettled question; but MM. Gumbel and Sandberger have now found, immediately above the Nummulitic (Eocene) strata of Bavaria, Oligocene deposits with beds of pitch-coal, gradually disappearing to the east and west, and corresponding, geologically and palæontologically, with the Cyrena-beds of the Mayence Basin. The marine deposits of Thaunen near Kempten, of Simmsee and Wagingersee, together with the lower strata near Passau, represent, within the upper Danubian Basin, the genuine Miocene deposits of Switzerland and the Vienna Basin; while the Littorinella-beds of the Mayence Basin, the upper freshwater Molasse of Switzerland, and the lignitiferous tertiaries of Wildshut and Thomasroith (Upper Austria) find their analogues in the freshwater deposits of Irsee, Irschenberg, and Weyarn, the upper strata of Passau, the beds of tertiary coal near Ratisbon and Abbach, and the strata near Ulm, Günzburg, and Kirchberg along the upper course of the Danube. [Count M.]

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## *On the* Geological Position *of the* Tertiary Strata *of* Sotzka, Styria. By Dr. Fred. Rolle.

[Proceed. Imp. Acad. Vienna, April 1858.]

Two papers on the fauna and flora of the Tertiary beds at Sotzka, near Cilly, in Southern Styria, have of late been published in the Proceedings of the Imperial Academy of Vienna, the one by Prof. C. von Ettingshausen, the other by Dr. F. Rolle. Prof. Unger was the first who published a monograph of the interesting fossil flora of this locality (Transact. Imp. Acad. Vienna, 1851), which, on account of its decidedly tropical character and its near affinity to the present insular flora of Australasia, he declared to be of Eocene date. Then, however, significative animal remains from the Sotzka strata were unknown. Prof. Unger's views on this subject did not remain uncontradicted; the celebrated Leopold von Buch contended that these deposits were of middle tertiary age; and Prof. Heer has more lately ranked them with the lower beds of the Swiss Molasse.

Prof. C. von Ettingshausen, on examining in 1853 the Eocene flora of Monte Promina (Dalmatia), found it to be highly concordant with the fossil flora of Sotzka. According to his judgment, 38 species among the 71 occurring at Monte Promina are also met with in the fossil flora of Häring, and 34 in that of Sotzka. With the plants of Monte Promina are associated characteristic animal forms, determined by Chev. von Hauer as *Neritina conoidea*, Lam., *Rostellaria fissurella*, Lam., *Diastoma costellata*, Lam. sp., &c. These circumstances, together with the stratigraphical relations, prove the deposits of these three localities to be contemporaneous, and consequently those of Sotzka to be somewhat older than Middle Tertiary.

Prof. C. von Ettingshausen has published the result of his investigations in the Proceedings of the Vienna Acad. vol. xxviii. p. 545. He found the majority of the Sotzka plants to agree with those of Häring (Tyrol), Sagor (Carniola), and Monte Promina (Dalmatia); and only a few of Miocene or Upper Miocene character. He regards therefore the fossil flora of Radoboj (Croatia), Parschlug (Styria), and others of similar character, to be of younger date compared with the Sotzka deposits.

Dr. Rolle (Proceedings, Vienna Acad. vol. xxx. p. 13, 1858) gives a zoological complement to these investigations. Having in

1855 and 1856 explored the environs of Cilly, by order of the Geological Society of Styria, he had the opportunity of studying other Tertiary deposits, connected with those of Sotzka. These last have been found to belong to an important series spreading far through Southern Styria, and containing several known Eocene forms besides undescribed species. The well-known Eocene locality of Oberburg afforded *Fusus subcarinatus*, Lam., *Natica Vulcani*, Brongn., *N. perusta*, Brongn., &c., together with Corals, also of Eocene date, such as *Astræa* (*Siderastræa*) *rotundata*, Cat. By its extent and its mode of stratification, the Eocene deposit of Oberburg is intimately connected with other Styrian deposits regarded as Eocene. Younger Tertiary beds also occur in the same district, but unconnected with those before mentioned, and containing only Upper Miocene shells, especially *Melania Escheri*, found also at Mulhouse (Alsatia), St. Gallen (Switzerland), and Ulm (Wirttemberg), and often in Southern Styria and Carinthia, and important in indicating the comparative age of the Tertiary beds, as it is wanting in the Lower Tertiaries and abundant in the Newer.

From this Dr. Rolle concludes that a considerable hiatus, not permitting the union of the lower with the upper deposits, exists between the Sotzka strata and the Upper Miocene beds with *Melania Escheri*, Brongn. This opinion is supported by the nature of the fossiliferous strata of Presberg (Styria), first investigated by Dr. Rolle. These contain plant-remains demonstrative of contemporaneity with the Sotzka strata, such as *Araucarites Sternbergi*, Goepp., *Podocarpus Eocenita*, Ung., *Cinnamomum lanceolatum*, Ung., *Banksia Haeringiana*, Ettings., *Eugenia Apollinis*, Ung., &c. The shells found by Dr. Rolle in the Presberg strata were undescribed, except *Cerithium dentatum*, Defr., characteristic of the Oligocene (Upper Eocene and Lower Miocene) deposits of Jeurre, near Paris, and Weinheim, near Mayence, and indicative of an horizon lower in position than the beds with *Melania Escheri*.

It is therefore highly probable that there are in Southern Styria two principal Tertiary subdivisions not connected by mutual transitions. The Sotzka strata represent the lower of these, probably corresponding to those of Jeurre, Versailles, Weinheim, &c.; or perhaps they are somewhat older,—a question still unsettled. They are certainly not higher than these, nor, as asserted by Prof. Heer, do they correspond with the lower freshwater Molasse of Switzerland, characterized by the presence of *Melania Escheri*, Brongn.

[Count M.]

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## *On the* Railroad-section *between* Laibach *and* Trieste. By Dr. Stache.

[Proceed. Imp. Geol. Instit. Vienna, June 1858.]

The town of Laibach is built on Upper Carboniferous (Gailthal) strata, which are overlaid near Ober-Laibach by Upper Triassic (Raibl) beds, partly abounding with *Megalodon Carinthiacus*, *Corbula Rosthorni*, and other characteristic bivalves. The thick layers of finely oolitic light-grey limestones of Loitsch, with remains of large Crinoids, together with the apparently non-fossiliferous strata lying on them, are regarded as Jurassic by Dr. Stache. At a short distance southward (from Loitsch to near Rekek), limestones, partly dolomitized, and containing *Rudistæ* and *Caprotinæ,* represent the Lower Cretaceous (Upper Neocomian) deposits; while the Upper Cretaceous (Turonian) are represented, from Adelsberg to Valenesina, by light yellow limestones, with beds of *Radiolites,* alternating locally with black bituminous slates (parallel to the fish-slates of Comen) and with Rudista-limestones. Nummulitic, resting on Cretaceous limestones (at high angles, and sometimes overhanging), overlaid by Eocene sandstones (Tassello), extend along the sea-coast from Nabresina to Trieste. All these complex Eocene beds show evidences of violent and manifold disturbance.

[COUNT M.]

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*On the* GEOLOGY *of the* COASTS *of the* BLACK SEA, SEA OF MARMORA, *and the* GULF OF CORINTH. By M. FŒTTERLE.

[Proceed. Imp. Geol. Instit. Vienna, June 1858.]

AN exploration of these coasts was made in the spring of 1858, in company with the lately deceased Mr. Porth. The blackish argillaceous slates, limestones, and quartzite-slates, reaching along both sides of the Bosphorus, extend north-eastward as far as Gehiseh; they contain Trilobites, Orthoceratites, Brachiopods, &c. They are succeeded by a powerful deposit of red sandstone, beginning at Gehiseh, in the Gulf of Zamid, forming the largest portion of the Aghatseh-Denisi and the Taila Mountains between Ismid (Nicomedia), Chandek, Uskab, and the Black Sea, and repeatedly touching the shore between Eregli and Samsun. According to MM. Tchihatcheff and Kotschy, this sandstone range continues eastward into the interior of Asia Minor. The lowermost strata of this sandstone are quartzose conglomerates, alternating with felspathic sandstones, deeply tinged with oxide of iron, abounding with *Calamites* and layers of shale, with very good coal-beds of 5 to 12 feet thickness, and they make their appearance between Eregli and Amassera. These shales contain remains of *Calamites transitionis, Pecopteris Geinitzi, Odontopteris obtusiloba,*—forms more characteristic of the Devonian than of the true Carboniferous deposits.

This sandstone is limited on the south by an extensive tract of melaphyre, traceable from Bos Burun on the Sea of Marmora (between the Gulfs of Ismid and Gaulik), through the Samanlii and Usun-Tschair Mountains, over Chandek, as far as the plain of the Usküb, where it ends at the crystalline slates and limestones on the southern slope of the Samanlii, the Usun-Tschair Dagh, the Göh Dagh, and the Kurmanlii Dagh, connected further southwards with Mount Olympus of Brussa. The red sandstone of the coast-mountains is frequently overlaid, between Ismid and Aktsche Schehr, by grey Cretaceous marls with *Inocerami,* passing locally into the state of compact limestone full of nodules of corneous silex.

The Nummulitiferous Eocene strata along the coast and in the interior of Asia Minor are remarkable for their great extent. Their marls, slates, and limestones range from the Gulf of Ismid to beyond Dudsche, and then occupy the southern and eastern slopes of the coast-mountains, and the south shoaly coast of the Black Sea from Eregli to beyond Samsun. These strata are nearly everywhere associated with genuine Macigno Sandstones, externally quite analogous to certain subdivisions of the Vienna Sandstone. The eastern coast of Asia Minor, between Samsun and Trebizonde, is almost wholly composed of trachytes; only on a few points (as near Unje) oolitic (probably Cretaceous) sandstones, and Eocene strata near Samsun, are of some importance.

The younger Tertiaries, running along the south coast of the Gulf of Corinth, and spreading inland to a height of several thousand feet, are solid calcareous conglomerates, overlaid by sandstones, marls, and sands, on which are several distinct terraces of horizontal diluvial beds. These Tertiaries rest on limestones of older data, and have been affected by the upheavals which the limestones have suffered, sloping steeply to the north. The deposits of fossil fuel here are too insignificant for profitable working.

A kind of Salfatara exists eastward of Kalamaki, where sulphur is deposited in crystals in the crevices and cavities, or in the interstices of the Tertiary gravel, yielding 20 to 50 per cent. of this substance. At present want of fuel is an obstacle to the exploitation of this mineral. [Count M.]

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### *On the* Railroad-section *from* Vienna *to* Linz. By M. H. Wolf.

[Proceed. Imp. Geol. Instit. Vienna, July, 1858.]

The cutting at Neulengbach (48 feet deep and 2400 feet long) shows marls with beds of sandstone (dipping 5°–10° at the west end, 30° at the east end, and 60°–70° in the middle), and above them variegated marl-slate, sands, and marls, with septaria of very diversified forms, some weighing several cwt., consisting of calcareous dark-coloured marl, symmetrically intersected with little veins of calc-spar. In some of them were found numerous specimens of *Pecten,* in another a *Terebratula*; at all events, it may be assumed that they are not post-eocene. The section between Sierning and Rehr exposes superficial loess, and a bed of freshwater limestone about 10 feet thick, with 3 inches of menilite-slate containing fish-scales. Nearer to Melk a bed of two or three species of *Ostrea,* pronounced by Prof. Suess to be Oligocene, was discovered. Further westward the road is cut through gneiss, granulite, and granite.

The analogy of the plastic clay ("Schlier") near Linz with the horizontal beds of "Tegel" in the Vienna basin is not distinct, on account of their dipping at a rather high angle. Remains of a young *Elephas primigenius* (an upper jaw with two teeth and the occiput) were found in the loess near Mautern, and are now in the Museum of the Imp. Geol. Institute. [Count M.]

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## *On the* Fossil Wood *of* Egypt. By Prof. Unger.

[Proc. Imp. Acad. Vienna, October 1858.]

Prof. Unger gave a notice of the fossil forest near Cairo, and of some other deposits of fossil wood in Egypt, which he had lately investigated in person. The so-called "fossil forest" near Cairo is an accumulation of wood-fragments spread over a surface of several square miles, and belonging, without exception, to the *Nicolia Ægyptiaca*, Unger. The fragments are loosely imbedded in the sand of the desert, between Cairo and Suez, and may be observed in their original situation, in Tertiary sandstone, at the Gibel Akmar, a locality strikingly analogous to the sandstone containing wood-stems near Gleischeuberg in Styria. Prof. Unger, in explanation of this phenomenon, supposes the masses of wood to have been drifted into a basin separated from the main sea and filled with water saturated with silica.

Another deposit of fossil wood, already known by specimens brought to Europe by M. Russegger, is near Assuan (Syene) on the Egypto-Nubian frontier. A third occurs near Um-Ombos, in the desert west of the Nile. The fossil wood of Assuan and of Um-Ombos belongs to an undescribed Coniferous tree, of the Araucarian division; and for it Prof. Unger proposed the systematic denomination of *Dadoxylon Ægyptiacum*. The original bed is undoubtedly the sandstone which occurs extensively in Upper Egypt and Nubia, between the Granite and the Cretaceous beds, but hitherto of doubtful rank in the Geological Series, as no organic remains have been found in it.

This fossil wood of Egypt, analogous to two species known to occur in the palæozoic (Devonian) rocks, may supply an argument for ranking in the Permian, rather than in the Keuper or the Cretaceous formation, the sandstone used by the ancient Egyptians for their colossal constructions.

[Count M.]

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## *On some* Tertiary Fishes *from the* Vienna Basin. By M. Steindachner.

[Proc. Imp. Acad. Vienna, April 28, 1859.]

M. Steindachner described four new species of fossil fish from the Plastic Clay of Hernals, near Vienna. Three of them (*Clinus gracilis*, *Sphyræna Viennensis* and *Caranx carangopsis*, Heck.) rank among genera now living in the seas of warmer climates; the fourth, *Scorpænodes siluridens* (of the Order *Cataphracti*), constitutes a new generic type. Prof. Suess has remarked that the occurrence of these undoubtedly marine species in the plastic clays, where also numerous remains of *Phocæ* and dolphins have been found, associated with those of a fluviatile Chelonian (*Trionyx*) and a notable quantity of vegetable fragments (amongst which are a *Proteacea* and a subtropical *Laurinea*), proves this clay to have been an estuarine formation, deposited at the mouth of a river.

[Count M.]

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## *On the* Marine Tertiary Deposits *of* Bohemia. By Prof. Reuss.

[Proc. Imp. Acad. Vienna, June 24, 1859.]

These Tertiaries, hitherto quite neglected, have been recently laid open by the railroad between Prague, Olmütz, and Brünn. They are the north-easternmost outliers of the Austro-Moravian tertiary basin, confined to a very narrow space around Trübau and Landskron on the eastern Bohemo-Moravian frontier. According to Prof. Reuss, these tertiaries, distributed in four distinct groups, are remains of a once continuous deposit in a narrow bay running from the Moravian plain into Bohemia. They appear under the form of plastic clay resting on Devonian or on Cretaceous rocks, and containing numerous organic remains. Prof. Reuss has found at Rudelsdorf no less than 202 distinct species, together with some few remains of Mammals and Fishes. The other localities gave only 23 species, of which only 6 are different from those of Rudelsdorf. A skeleton of *Dinotherium giganteum* was discovered, some years ago, in the plastic clay of Abtsdorf. The palæontological character of the strata in question is the same as that of the youngest neogene deposits in the Vienna basin. They may be best compared, in this respect, with the upper Leitha-limestone of Steinabrunn. The individual shells found in them are of remarkably small size,—a circumstance which, in conjunction with other peculiarities, favours the supposition that the Eastern Bohemian Tertiaries were deposited (towards the close of the Miocene period) at the margin of a very shallow bay, in which the saltness of sea-water had undergone sensible diminution from the access of river-water.

[Count M.]

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## *On* Silica *in* Igneous Rocks. By Baron Richtofen.

[Proceed. Imp. Geol. Instit. Vienna, March 15, 1859.]

In quartziferous and trachytic porphyries silica occurs constantly in the shape of perfect crystals; while in the different varieties of granite, crystals of other mineral substances are generally impasted in the quartz. The chemical and mineralogical composition* being identical in the three quartziferous types of the granitic, porphyritic, and trachytic series, the differences in their exterior evolution can only be accounted for by the circumstances in which they underwent solidification. In the granite the orthoclase and oligoclase were solidified previously to the quartz: an anomaly explained by the difference between the point of solidification and the point of fusion, and by a protracted viscosity of the quartz: an opinion quite admissible if applied to the slow refrigeration of a liquid magma on the surface of the ground. In the quartziferous and trachytic porphyries, quartz was first segregated; then orthoclase and sanidine, and lastly oligoclase. These two groups of rocks having been protruded at a far later period, when refrigeration of the earth's crust had greatly progressed, two phases of solidification must be distinguished: one of very slow refrigeration, coinciding with the general refrigeration of the globe; the other more accelerated, beginning only after protrusion on the surface. The first gave origin to the most refractory minerals; the other to the felspathic paste: the sharp outlines of the crystals imbedded in it prove the change of circumstances to have taken place without transition.

The quartziferous and trachytic porphyries of the Old Red and Trias periods exhibit other peculiarities. In the first of these rocks, silica is constantly crystallized in double pyramids without any prismatic planes; in the second of them, the prismatic planes, though constantly subordinate to those of the pyramid, generally make their appearance. In some varieties of undulated structure silica remained partly within the fundamental paste and unequally distributed within it. In the trachytic porphyries the silica forms well-defined milk-white veins resembling chalcedony.

[Count M.]

* The slight differences between orthoclase and sanidine not being regarded.

## *On some* Tertiary Corals *from near* Mayence. By Prof. Reuss.

[Proceed. Imp. Acad. Vienna, April 14, 1859.]

Prof. Reuss, of Prague, described six new species of *Anthozoa* from the Lower Marine Sand of Weinheim and Waldböckelheim, near Kreutznach, communicated to him by Prof. Fr. Sandberger, of Carlsruhe. These six species are the first from Oligocene strata which have hitherto been exactly described as essentially different from those occurring in Tertiary strata of other localities. Three of them belong to the genus *Bathonophyllia* (*B. granata*, *B. inæquidens*, and *B. fascicularis*), represented in the living creation by the species *B. verruciaria*. The fourth is *Cyathina brevis*. The fifth (*Crenocyathus costulatus*) is the first known fossil species of this genus, represented by some few recent species. Although allied closely to *Cyathina* on account of its internal structure, it differs strikingly from it by its ramose polypary. The sixth species, with a laminiform axis, seems to represent a probably new generic type (*Plæopsammia*) of the order *Eupsammidæ*. [Count M.]

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## *On the* Geographical Distribution *of the* Brachiopoda. By E. Suess.

[Proceed. Imp. Geol. Instit. Vienna, July 7, 1859.]

About seventy-six species of this class, distributed into fourteen genera, of which two have their representatives among the Palæozoic Fauna, are at present known to live in the seas of our globe. All the species with corneous shells are littoral, or at least not living in depths beyond 19 fathoms; while those with solid and opaque shells (with only two or three exceptions) live in greater, and sometimes very considerable depths. The geographical distribution of by far the greater number of existing Brachiopods is essentially sporadic. Of fourteen species of *Terebratella*, one lives on the coasts of Spitzbergen, another on those of Labrador, a third in the Sea of Ochotsk, another in the Straits of Magellan, a fifth in the Bay of Algoa, one on the coasts of Java, another on those of Valparaiso, an eighth near the Philippine Islands, two on the coasts of Corea, and the last four on those of New Zealand. Only two genera have fixed geographical centres; one of them is *Morrisia*, the three species of which are exclusively Mediterranean. The geological age of the sporadic genera is far more remote than that of the geographically confined genera. It may be inferred from this circumstance, that, at former geological periods, the at present sporadic genera had circumscribed geographical ranges, subsequently disturbed by repeated changes in the distribution and mutual connexion of seas and continents,—a supposition confirmed by the study of the geographical distribution of other animal classes, especially of Insects. [Count M.]